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TOP PROJECTS
Vol.10

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PROUDLY PRINTED IN AUSTRALIA

nd held 20 MHz digital equency/period meter eatures liquid crystal display

This project features a 4½-digit liquid crystal display and is completely portable as it's battery powered. It counts to 20 MHz in four ranges (2 kHz, 20 kHz, 2 MHz, and 20 MHz) and measures period from 200 ms to 200 us (full scale).

Part 1

Geoff Nicholls

NO MATTER HOW you're involved with electronics, there's always a need to measure various quantities — voltage, current, resistance, frequency, etc. What you want to do is put a *number* to that quantity and the best way to do that is to employ a digital display.

Digital displays, based on neon-filled vacuum tubes called 'Dekatrons' first appeared in the late '50s-early '60s. With the advent of seven-segment LED displays, digital measuring instruments rapidly became commonplace. With the introduction of liquid crystal displays, which require virtually no power to operate, battery-operated portable measuring instruments burgeoned.

Portable instruments can be used almost anywhere — right where you want to make the measurement. It's not always possible or convenient to take the equipment to the workshop. The majority of multimeters are portable, handheld devices and we thought, "why shouldn't a frequency meter be the same?"

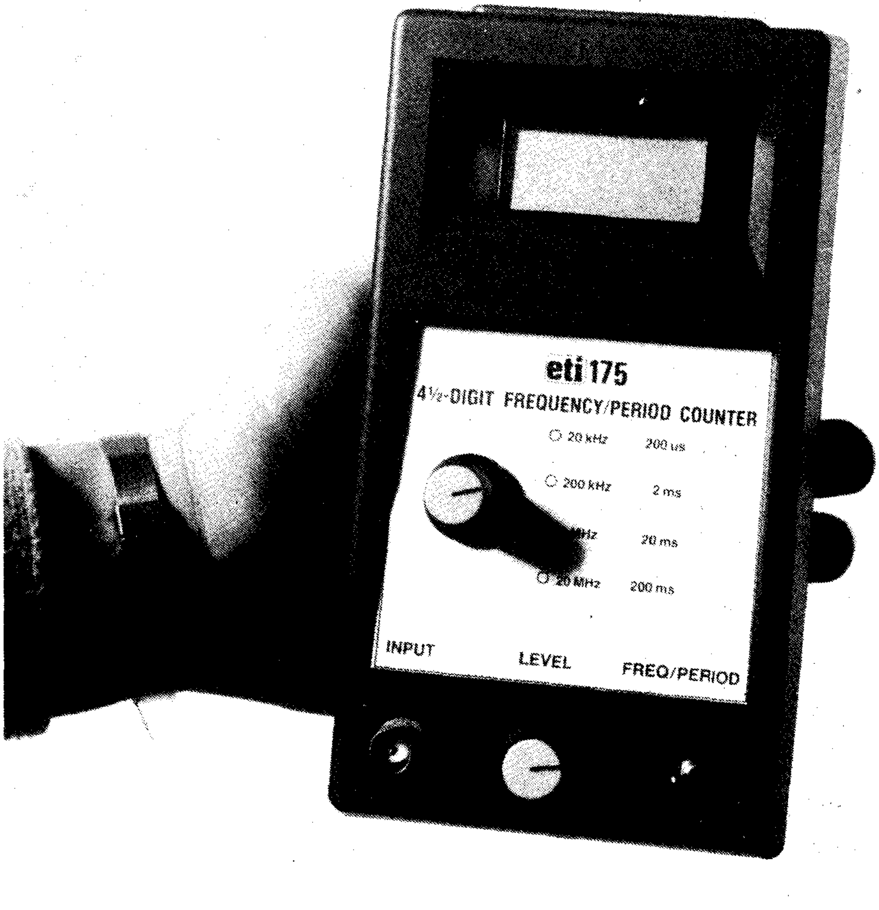
There are so many occasions in electronics today (... err, pardon the pun) where you need to measure frequency. In times past, it was almost the exclusive reserve of 'the RF man'. These days even those involved in audio and computing need to have frequency measuring facilities.

Just being able to measure frequency is great, but what sort of accuracy is generally required? I asked around and, for the great range of applications, it seems six-figure accuracy, while seemingly desirable, is not really necessary.

Take a computer modem for example. These use two audio tones to signal the 'high' and 'low' bits of the digital information transmitted through them. The accuracy required is a few Hertz in several thousand Hertz — about 0.1%.

The accuracy and temperature stability of your 'off-the-shelf' quartz crystal is 100 parts per million (ppm) and 20 ppm/°C, respectively. Put another way — 100 Hz per megahertz accuracy, 200 Hz per megahertz for a 10°C temperature range.

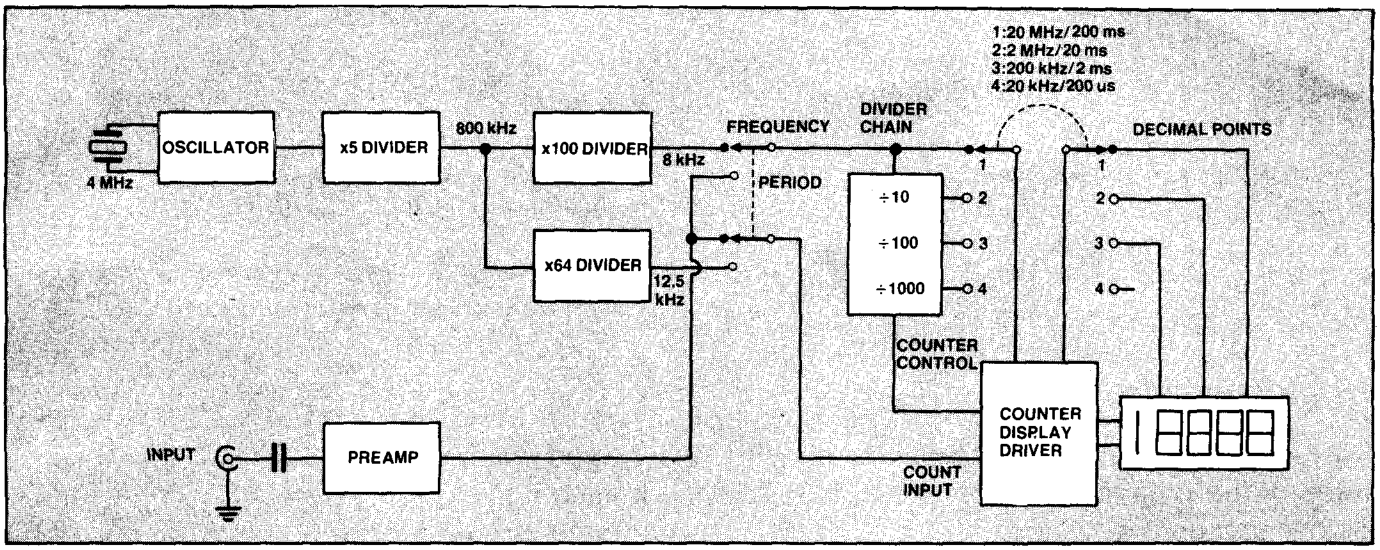
All that adds up to this — a 4½-digit display has all the accuracy you need for the greater range of applications. (The left-most digit on a 4½-digit display will only read '1', while the other four will read 1 to 9).



That's when I went searching for a 4½-digit counter-display driver as 4½-digit liquid crystal displays are readily available.

I turned up Intersil's ICM7224IPL, which is perfect for the job, and what's more, it's capable of counting to 20 MHz! A portable, battery-operated digital frequency meter was a distinct possibility, so I obtained several samples from R&D Electronics, the Intersil agents, through All Electronic Components in Melbourne.

Many months before we tackled this design, a representative from Mayer Krieg & Co had called in and left us a range of sample 'Unimes' cases, amongst which was a small handheld case just made for the application. It was palm-sized and featured a 'sculpted' front with a window just the right size for a liquid crystal display. It also had a battery compartment to take a



Block diagram. Showing overall design of the counter. The preamp was eventually found to be unnecessary.

standard No 216 9 V battery.

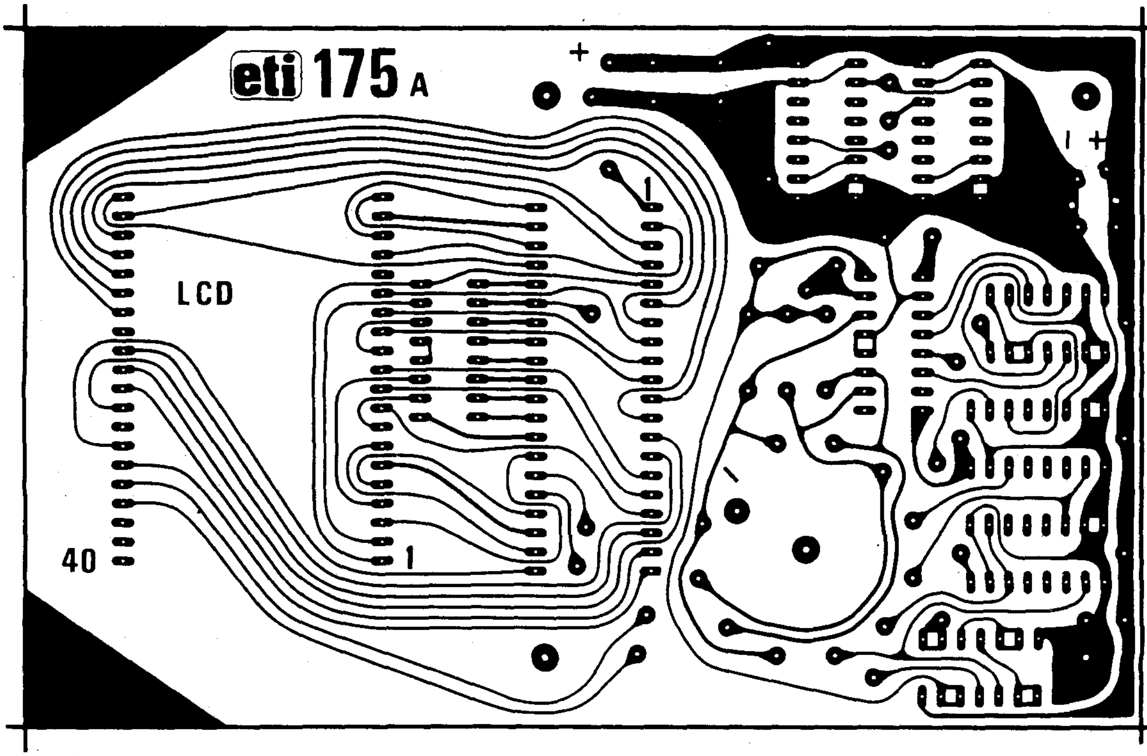
The electronic design was a 'snack' but it was obvious that fitting the components on a pc board and into that case was going to require some pretty fancy juggling. Right here, Murphy stepped in. After considerable effort with the mechanical design, it was abandoned and another case sought. But Mayer Krieg came to our rescue with a somewhat larger handheld case with all the features we wanted. Known as the Unimes 2, it measures 180 mm long by 100 mm wide and from 35 to 44 mm deep. It has a battery compartment in the rear to take 4 x AA cells, plus a wire tilting bail so that the case can be either laid flat or stood up on a flat surface. There is a recessed window in the front, up top, for a display and a recessed, sloping section for a front panel label.

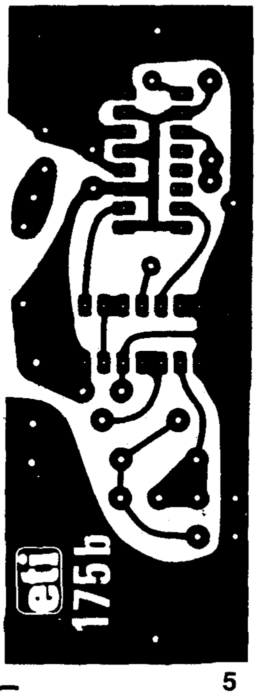
Design

Frequency counter designs may be classified according to the type of range switching employed. In low-cost designs there are only two common types, the *switched gate period* type and the *input divider* type. The latter divides the input signal down by various ratios, according to the range selected, while keeping a fixed gate period, typically one second. This allows the actual counter to operate at a low frequency while counting a high input frequency but requires high speed dividers for one or two stages. I decided to take advantage of the excellent high frequency counting ability of the Intersil ICM7224IPL and use a switched gate period. The block diagram here shows the overall arrangement of the instrument.

The count input of the Intersil device has a Schmitt trigger first stage with a typical hysteresis of 0.5 V, centred on 2.0 V. When operating in the frequency mode, the preamplifier output is fed to the COUNT input while the 8 kHz reference is divided to select gate times of 1 ms, 10 ms, 100 ms or one second, corresponding to ranges of 20 MHz, 2 MHz, 200 kHz and 20 kHz. The actual gate time is eight cycles of the frequency sent to the divider chain.

In period mode, the count input of the ICM7224IPL is switched to a fixed 12.5 kHz reference, while the input signal from the preamplifier goes to the divider chain. Once again, the gate period is eight cycles, so the counter ends up counting at the rate of 12.5 kHz for eight input periods. This produces a 'true' decimal period readout in microseconds or milliseconds.





Handheld 20 MHz digital frequency/period meter with liquid crystal display

Geoff Nicholls

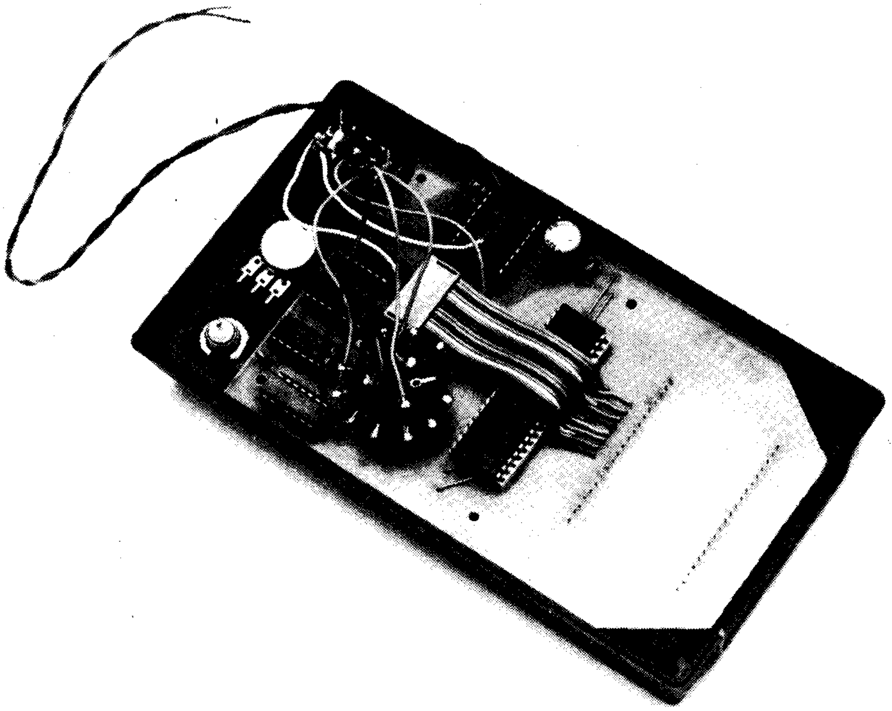
Part 2

Part 1 of this series described the general design and features of the project. Now comes the nitty-gritty — putting it together and getting it going.

THE PROJECT is constructed on two printed-circuit boards designed to fit into the Unimes 2 case from Mayer Krieg. This case comes in two parts — a front and a rear. The main printed-circuit board, ETI-175a, carries the majority of the circuitry and mounts in the front part of the case with the liquid crystal display positioned so that it can be viewed through the 'window'. The two 'top' corners of this board are trimmed at an angle so as to clear the moulded-in pillars at the inside top corners of the case front. The rotary selector switch mounts on the ETI-175a board and I have marked a 'keyhole' which should be drilled to take the locating spigot of the Lorlin switch. This prevents the switch from twisting on the board when it is operated. A small '1' mark on the board copper side indicates where lug 1 is to be lined up when assembling the switch to the board (this lug is not actually wired in).

The liquid crystal display mounts on the *copper side* of the board and is soldered directly in place without a socket.

The ICM7224IPL counter/display driver chip, a 40-pin device, mounts on the component side of the board. Owing to the restricted space and large number of interconnections between the liquid crystal display and the ICM7224IPL, I decided to use 16-way ribbon cable to bring out the counter control signals and the decimal point connections to the liquid crystal display. At the time, I hoped to use insulation displacement plugs at either end of a short length of ribbon cable with 16-pin IC sockets either side of the counter chip to effect the connections easily. Murphy had other ideas and I found that the ID plug at the 'top' end of the board fouled the battery compartment when the two halves of the case were put together. Thus, it was necessary to solder in the ribbon cable at the liquid crystal display end of the board, as can be seen from the accompanying internal photograph. I used an ID plug at the other end of the ribbon cable, and this goes into a 16-pin IC socket, thus allowing access to the ICM7224IPL device by simply unplugging the cable. I recommend you use a low-profile 40-pin socket for the counter chip. Sockets for the other ICs are optional.



Inside the lid. Showing general assembly of the main pc board and how it fits in the case. This picture was taken before the input wiring was completed. Note the ribbon cable and ID connector linking system.

A cardboard 'mask' with a hole for the display to be viewed through was used to 'mask-down' the area of the case window. I painted it black and glued it in place.

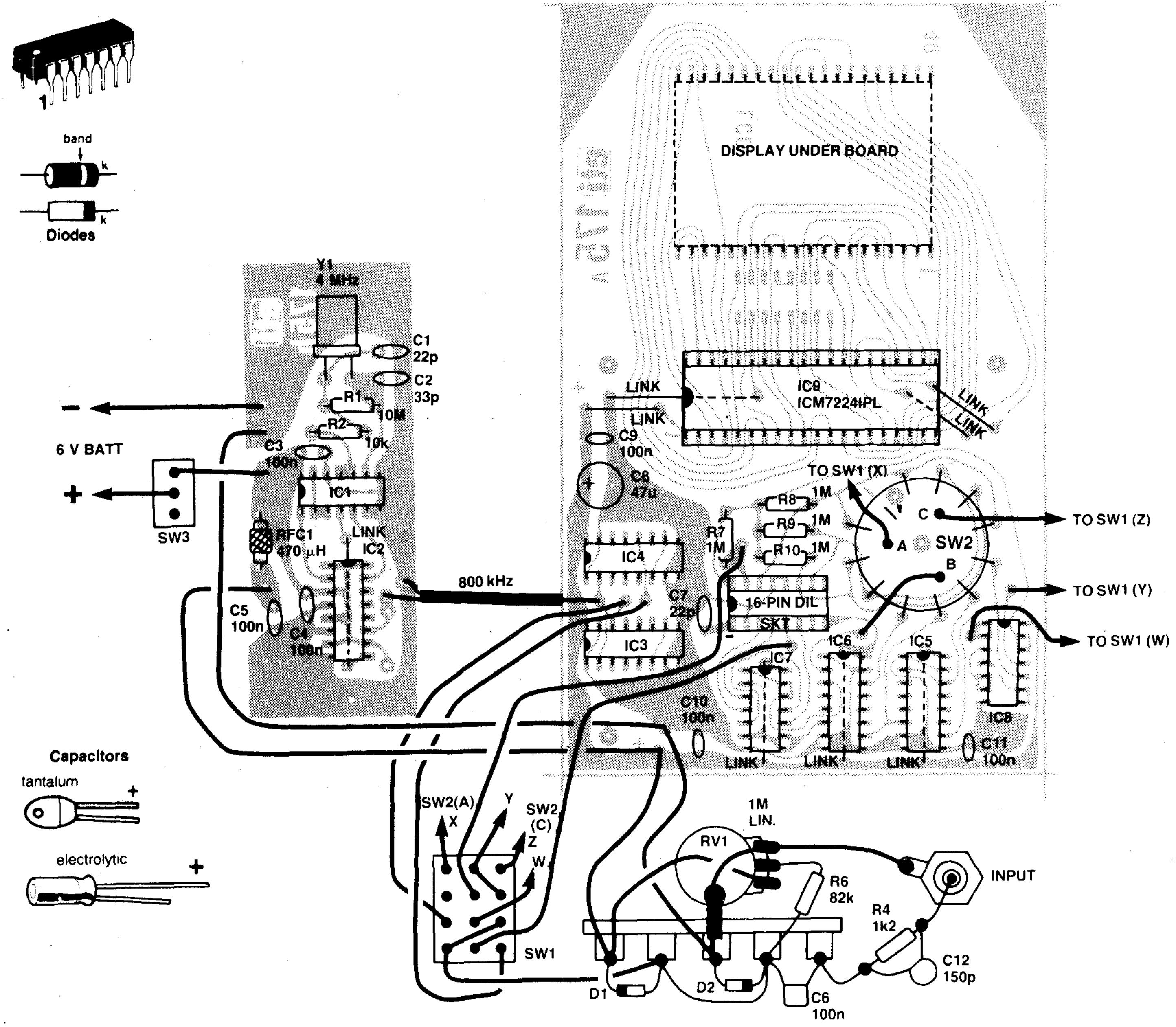
The second, and smaller pc board (ETI-175b) houses the crystal oscillator. This board mounts in the rear section of the Unimes case, right next to the battery compartment.

Construction

No matter whether you've purchased pc boards for this project or built your own, the first thing to do is carefully check each board, looking for incorrectly drilled holes, cracks in the copper tracks and copper 'bridges' between closely-spaced tracks. Fix any faults before proceeding. Check that each board fits into its position in the case halves.

Mark out and drill the case first. Use the ETI-175a pc board as a template to mark out the position of the shaft hole for the rotary switch. The input BNC socket, freq/period toggle switch and level pot mounting hole positions can be marked out next. Note that level pot is a 'miniature' type with a 17 mm diameter body but a standard 6 mm diameter shaft. See that the freq/period switch body does not foul the adjacent case mounting pillar.

The on/off switch is mounted in the side



PART LIST — ETI-175

Resistors	all ¼ W, 5%
R1	10M
R2	10k
R3	1k (optional)
R4	1k2
R5	1M (optional)
R6	82k
R7, 8, 9 10	1M
RV1	1M/A min. 1in. pot.
Capacitors	
C1, C7	22p ceramic
C2	33p ceramic
C3, 4, 5, 6, 9, 10, 11	100n 'bluechip' ceramic
C8	47μ/25 V RB electro.
C12	150p ceramic
Semiconductors	
IC1	74HC02
IC2	74HC160
IC3, 5, 6	4518B
IC4	4520B
IC7, IC8	4011B
IC9	ICM7224IPL
Miscellaneous	
LCD1	4½-digit liquid crystal display (eg: D.S.E. no. Z-4157 or similar)
SW1	three-pole, four-position Lorlin rotary switch, or similar.
SW2	4PDT min. toggle switch
SW3	SPST min. toggle switch

ETI-175a & bpc board; Scotchcal front panel; case — Unimes 2, part no. 90 61 011 with tilting bail, battery clips etc (see text); 16-pin IDC DIP plug; 16-pin IC socket; about 100 mm of 16-way ribbon cable; 4 MHz HC18/U crystal; two knobs; BNC socket with earth lug; wire etc.

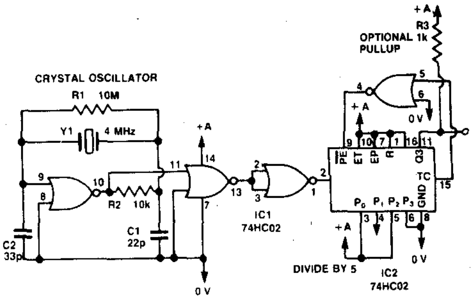
Price estimate $65 - $70

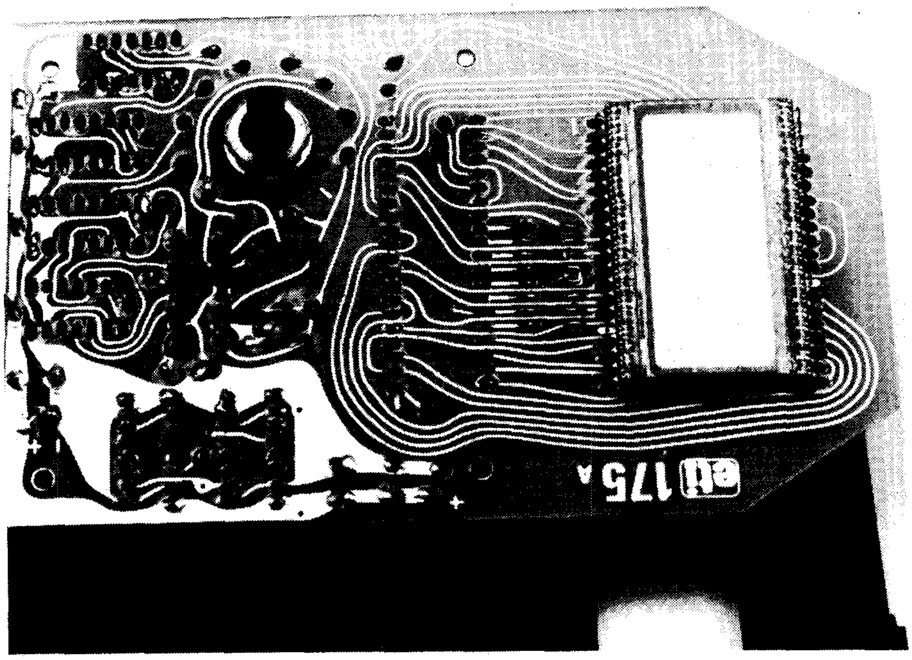
wall of the base, at the left hand side, adjacent to the battery compartment (see internal photograph).

Take care when drilling, centre punch all holes and drill a small diameter pilot hole to start with. This way, you'll avoid expensive traumas with the case.

Now you can tackle the pc boards. It's probably wiser to start with the smaller board (ETI-175b). The link should be soldered in first. Then you can assemble the components in any convenient order, but make sure you get the semiconductors correctly orientated.

The ETI-175a board is a little trickier. Install the links first. If you've elected to use sockets for the ICs, these should be installed next, followed by the resistors and capacitors. Make sure you get the polarised capacitors the right way round.





Display. View of the copper side of the main board showing how the liquid crystal display is mounted. The display comes with a clear film stuck to its face having arrows imprinted on it, the direction of the arrows indicating the pin 1-pin 40 end of the object. Note also the hole for the locating spigot of SW2.

Mount the rotary switch, positioning pin 1 above the marked position as explained earlier. Bend lug 1 *in*, toward the switch centre, then bend the other 11 lugs outward, carefully bending them as near to the base as possible and at right angles so they lay against the switch body. Wire them to the board with short lengths of tinned copper wire. If you're soldering the ICs in place, now's the time to do them.

Install the ribbon cable link next. Take an 80 mm length of 16-way cable and put an ID connector on one end. Strip and tin the wires at the other end then solder them in place at the LCD end of the board as shown on the overlay. Refer to the internal photographs, too.

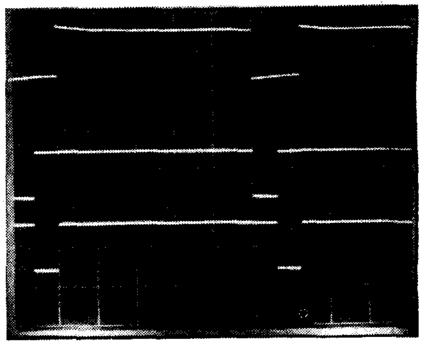
The liquid crystal display is installed last of all. It mounts on the *copper side* of the board and is soldered directly in place. To avoid possible 'solder bridge' shorts to tracks running between the pins of the display, I found that an ordinary soft-lead pencil carefully *rubbed onto the tracks passing between the LCD pins* helped prevent solder bridges. Before soldering the LCD in place, insert it in the board and then hold the board in the lid while you position the display to sit flush against the cutout.

With the two pc boards completed, check them both thoroughly, looking for dry joints, missed soldering and solder bridges between adjacent pads.

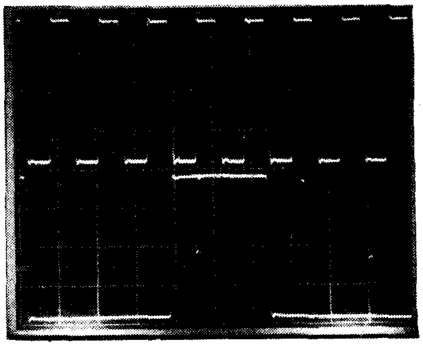
Install the wires that run between the two boards and the flying leads to the external components, then screw both boards into the case. Solder the tagstrip for the input components on the rear of the level pot., followed by the components. Then complete the wiring and you're ready to fire it up.

Install the batteries and switch on. The display may read something random. Set it to read frequency and connect a known signal to the input. Set the level control to get a sensible display. On switching to period, the minus sign will be shown. Check that the display reads correctly and it's ready for use. ●

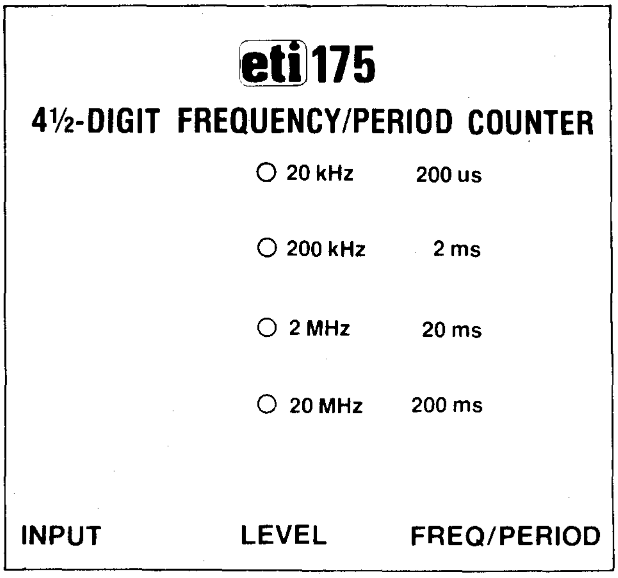
Printed circuit artwork. We have not reproduced artwork for the two ETI-175 pc boards owing to lack of space. However, you can obtain a print, free of charge, by sending us a stamped, self-addressed envelope (A4-size) and requesting "ETI-175 Artwork". Film transparencies can also be obtained — see Shoparound in this issue.



Waveforms — A: Upper trace — pin 10 IC7, COUNT INHIBIT. Middle trace — pin 4 IC7, STORE. Lower trace — pin 3 IC7, RESET. (Vertical — 5 V/div.; Horizontal — 200 μs/div.).



Waveforms — B: Upper trace — pin 1 IC1, 4 MHz oscillator. Lower trace — pin 11 IC2, 800 kHz output. (Vertical — 2 V/div.; Horizontal — 200 ns/div.).



Front panel. Full-size artwork for the project's front panel.

PERFORMANCE ETI-175

Sensitivity

100 mV RMS, 5 Hz — 2 MHz

250 mV RMS, 10 MHz

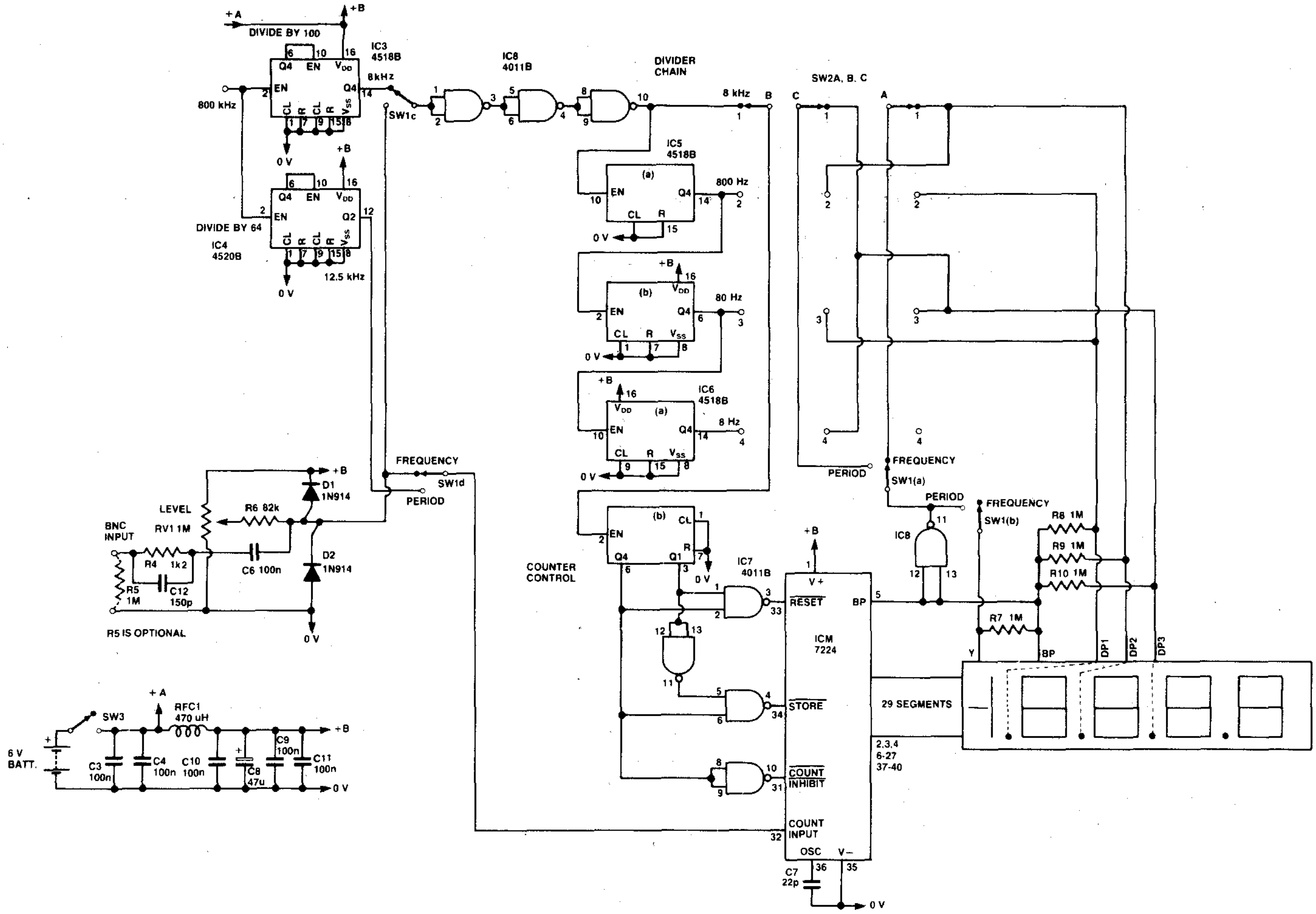
350 mV RMS, 20 MHz

Power supply

4 x AA cells (6 V nom.)

Current drain

7mA



HOW IT WORKS ETI-175

Part 1 gave a block diagram and overview of the project design, so let's get down to the circuit details.

DIVIDER STAGES

IC3 divides the 800 kHz from the crystal oscillator section down to 8 kHz by cascading its dual BCD counters.

IC4 is a dual binary counter connected to divide by 64 and thus produces 12.5 kHz.

IC5 and IC6(a) are BCD counters cascaded to provide four decade-related frequencies that are used for range switching by rotary switch SW2B.

COUNTER CONTROL

The control section centres on a BCD counter, IC6(b) and a quad NAND gate IC7. The BCD counter is clocked by a frequency selected from the divider chain via the rotary switch. The outputs Q4 and Q1 from the counter are gated to derive the counter control signals RESET, STORE and COUNT INHIBIT. The oscilloscope photo No. 1 shows the relation between these signals.

Note that Q4 in a BCD counter is low for eight clock cycles and high for two cycles. Therefore the ICM7224 will count for eight cycles of the IC6(b) clock (pin 2), store the count in its output latch on the next cycle, then reset its counter on the following cycle to complete one decade count of IC6(b).

FREQUENCY MODE

To display frequency in decimal units, the clock for the divider chain is switched to 8 kHz by SW1(c), while the input signal from the preamp is directed to the COUNT INPUT of the ICM7224 by SW1(d).

Now since the counter control section divides the incoming frequency by eight to control the ICM7224 count gate, the effective gate times selected by SW2B are 1 ms, 10 ms, 100 ms and 1 s to provide the four frequency ranges 20 MHz, 2 MHz, 200 kHz and 20 kHz respectively.

SW1(a) selects SW2A to activate the decimal points required for each range. Note that no decimal point is displayed for the 20 kHz range.

PERIOD MODE

To display the period, the input signal and clock reference are interchanged, thus effectively displaying the inverse of frequency i.e: the period. The same clock reference frequency cannot be used for both period and frequency, due to the divide by eight inherent in the counter control circuit.

Thus the clock reference is changed from 8 kHz to 12.5 kHz, and is directed to the count input of the ICM7224 by SW1(d). So if the input period is 100 ms and the 200 ms range is selected, then the ICM7224 will count

8 x 100 ms x 12.5 kHz = 10 000

which is displayed as 100.00.

To get the same count on the 20 ms range, the input period must be 10 ms, but the count is extended to 80 cycles. Similarly, the number of periods counted on the 2.0 ms range is 800 while 8000 cycles of the input period are counted on the 200 μs range.

The minimum period that can be measured is limited by the speed of the CMOS BCD dividers and is about 0.5 μs. Such small periods are normally measured on the frequency range and calculated.

SW1(b) turns on the minus sign annunciator in the LCD display to signify the period mode, while SW1(a) selects SW2C to display the decimal points.

OSCILLATOR/DIVIDER

The 4 MHz oscillator uses one gate from a 74HC02 (IC1), two other gates from this being used as buffers. A 74HC160 presettable counter (IC5) is arranged to divide the 4 MHz oscillator output by five to provide 800 kHz for the counter. As a 74LS160 may be used here, an optional pullup resistor, R3, can be added to the output for it (pin 11).

THE ICM7224IPL

This chip is made by Intersil Inc., of Cupertino California USA. It is imported by R & D Electronics and All Electronic Components of 118 Lonsdale St, Melbourne 3000 act as their retail distributors.

Project 1502

An electronic sling psychrometer

'What in the name of Beelzebub's left horn is a sling psychrometer?", I hear you ask. The very name itself conjures up images of smug mid-Victorian (era, not state) scientists airing their knowledge of classical languages. The machine is nowhere near as complicated as its name though, and all it does is measure humidity, or the amount of moisture in the air.

Ian Thomas

TO MOST OF US humidity is a rather poorly understood quantity and we are only aware of it when we are hot and sticky and our cold tinny leaves wet rings all over the place. The measurement and control of humidity, however, has a host of applications in industry and research as well as at home. For example the growing of a lot of exotic plants requires that the humidity where they are raised be kept under some sort of control.

Before we go on to the actual construction of the project and how to use it, it is interesting to look at the phenomenon of humidity itself and how it is defined and measured.

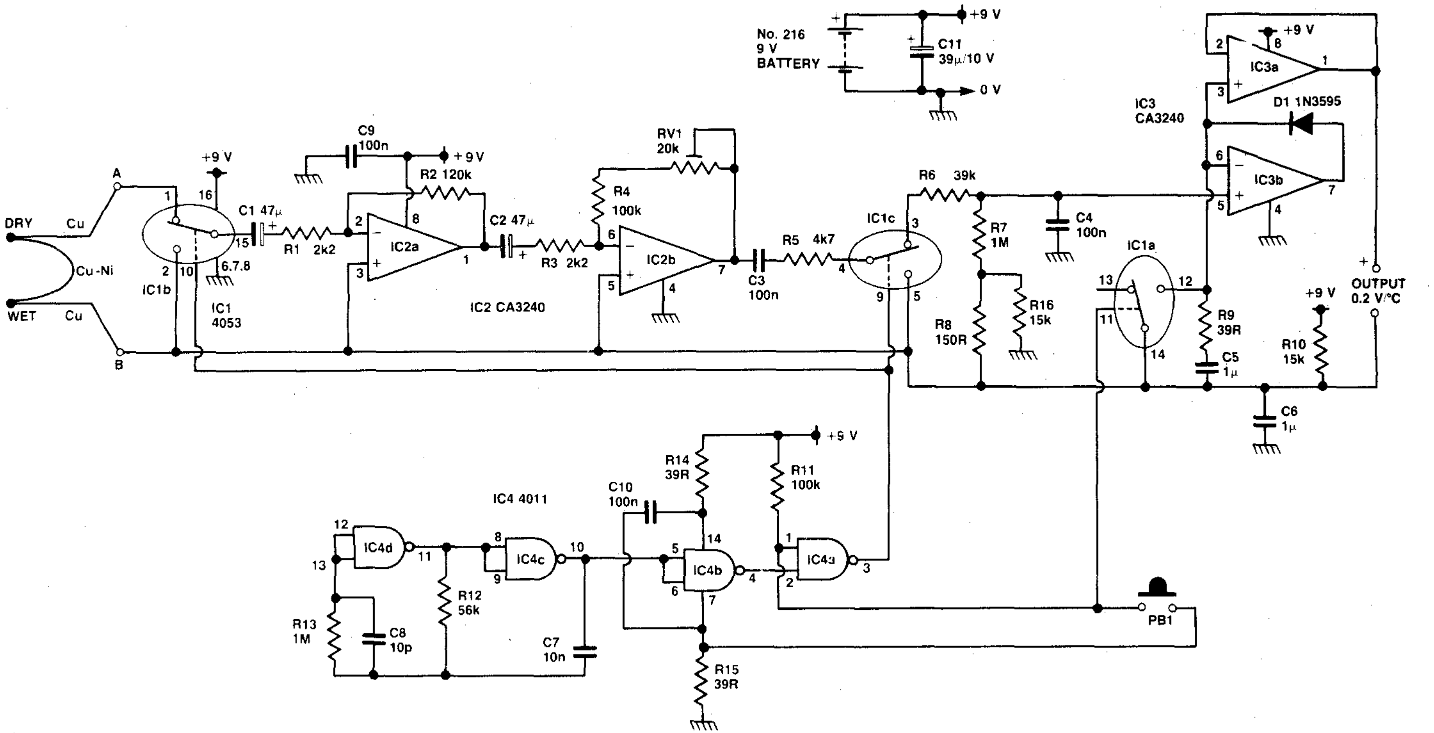
Humidity

Humidity is simply the amount of water vapour that is present in the air, but this seemingly straightforward quantity can be measured in many ways. Probably the easiest to understand is *Absolute Humidity* which is simply the amount of water vapour, expressed as either a mass or volume, that is contained in a given amount of air. This can be expressed as parts per million on a volume basis or mass basis, or grams per kg of air (or, in all probability in days gone by, decigrains per cubic rood — please don't ask me to define it). These units are nice and easy to understand but don't directly relate to the subjective feeling of how comfortable or uncomfortable we feel.

Another way of expressing Absolute Humidity is to measure the Dewpoint of the air. Air at a given temperature is only capable of holding so much water and the hotter the air the more water it will hold. If air that contains a certain amount of water is cooled to below its Dewpoint then the water will come out as a liquid (fog, rain or dew) or solid (snow or frost). The relationship between the Dewpoint temperature and absolute humidity is very well known and tables are published giving the exact amount of water vapour that is present for a given Dewpoint.

Measuring the Dewpoint is an accurate way of determining humidity but it's a bit clumsy as you have to have a method of cooling the air to see when mist or frost starts to form. This is usually done by cooling a mirrored surface in the air until it starts to mist over, then measuring the temperature of the surface. Another way is to expand the air to cool it and measuring the temperature of the air when fog starts to form. Either way is 'fiddly' at best and can give rather variable answers depending on how things were set up.

By far the most common way of expressing humidity is *Relative Humidity*



and this is how you see it on the weather forecasts. Relative Humidity is the ratio of the amount of water vapour present in a given volume of air to the amount of water vapour that would be present if the air had its Dewpoint at the same temperature. It shows how much water is in the air as a ratio of how much water the air will carry before mist starts to form and is a very good indication of how we feel (sticky and uncomfortable means close to 100% and sore throat and eyes hurting means close to 0%). The measurement of relative humidity can be done in many ways also, depending on whether the readings are wanted continuously for control purposes or just spot readings. This brings us to the project for this article; the psychrometer.

We're all aware that if a surface is wet and air is blown over it then the surface is cooled (the fact is drawn to our attention when we get out of a swimming pool on a windy day).

This principle is used to make measurements of Relative Humidity.

Normally, two mercury-in-glass thermometers are used with one thermometer's bulb surrounded in water-soaked cotton.

The two thermometers are mounted in a 'sling' so they can be whirled around in the air to create a draught.

The dry bulb thermometer records the ambient air temperature and the temperature difference between the two thermometers gives the so-called Wet Bulb Depression or the degree of cooling caused by the water on the wet bulb. Using these two figures it is possible to look up the Relative Humidity from tables.

The whole assemblage of thermometers, sling, water reservoir and wick to cover the wet bulb, is called a *sling psychrometer* and so long as the wick is kept clean and pure water is used, will give reliable and accurate humidity readings.

HOW IT WORKS — ETI-1502

The circuit can be divided into six separate stages which will be described separately. They are:

(1) The temperature difference sensing thermocouple. **Thermocouples have been used for many years and can give very accurate temperature measurements. Even today they are still used to calibrate semiconductor diffusion furnaces where the temperature must be correct to about ¼°C at 1100°C, a remarkable feat of control. Our needs are not quite so dramatic but as the voltages out of a thermocouple are very small, care must be taken.**

The couple used is copper-constantan one which gives, for small temperature differences, about 38.5 microvolts per °C. Constantan is an alloy of 60% copper and 40% nickel and the copper constantan couple is normally used between −200°C and +300°C. The thermocouple consists of two pieces of copper wire which are soldered onto the printed circuit board close together. The two free ends of the wires are connected together by a piece of constantan wire. About five millimeters of the copper and constantan wire are twisted together tightly to form the actual couple and may be soldered if the same solder is used for both junctions. The junction whose copper side is connected to the low voltage terminal is the cold junction (in our case the junction which is covered with wet cotton wool) and the junction whose copper side is connected to the amplifier input is the hot junction.

(2) The input chopper. **This is a simple CMOS analogue switch which, in this case, is a CD4053BE. The integrated circuit consists of three separate single-pole double-throw semiconductor switches, all of which have separate control inputs. The thermocouple is connected to one input of the switch and the other input is connected to a reference voltage which is common to the whole circuit. The control line for the switch is driven from a 500 Hz square wave so that the output from the switch is a 500 Hz square wave with an amplitude equal to the thermocouple voltage (plus a few bonus spikes from the switching).**

(3) The ac amplifier. **The low level signal from the input chopper is then amplified up through two stages using common or garden operational amplifiers. C1 ensures that the first stage of gain has unity gain for dc and the two resistors R1 and R2 set the gain for ac signals. It is about 54.5 for the stage, which is still well below the open loop gain for the op-amp at the chopping frequency so the gain will be stable with temperature and power supply voltage. The output from the first stage is ac-coupled to the second stage through C2 and the second stage gain is set by R3, R4 and RV1. RV1 is used to calibrate the gain of the whole amplifier so the output of the complete circuit is 0.2 volts/°C. The output of the amplifier is a square wave whose peak-to-peak voltage corresponds to the dc voltage we want.**

(4) The synchronous switch for dc recovery. **In order to convert the square wave out of the amplifier into a dc voltage again a second section of the CMOS analogue switch is used. The ac signal from the amplifier is coupled through a capacitor C3 (and resistor R5 to prevent any large currents from flowing and upsetting the op-amp output) to the 'pole' of the analogue switch. One switched output from the switch is connected to the common reference voltage. The other output is connected to a simple RC low pass filter formed by R6 and C4. The control line for the analogue switch is driven from the same signal that drives the input chopper. When the input chopper connects the reference voltage to the amplifier input the amplifier output is also connected to the same voltage and C3 is charged to any residual dc voltages that may exist due to op-amp offsets.**

When the input is connected to the thermocouple input the amplifier output is switched to R6 and charges C4 to the amplified thermocpouple voltage. The overall effect is that the output analogue switch acts as a very accurate fullwave rectifier and converts the ac output from the amplifier back into a dc voltage referred to the common reference voltage.

Because the two amplifier stages together have a gain of about 2500 as well as amplifying the thermocouple voltage, a lot of noise and switching spikes are amplified as well. R6 and C4 filter these out so the dc signal on C4 is an accurate representation of the dc input. Resistors R7 and R8 form a bleed so that when the whole circuit is reset C4 is discharged to the reference voltage (more about this later).

(5) The output peak hold circuit. **The dc voltage on C4 will vary as the temperature changes on the thermocouple input and, as we want to measure the largest voltage we can generate by whirling the whole thing around in the air, we need a way of capturing the peak output so it can be measured at leisure. This is done by IC3 and C5.**

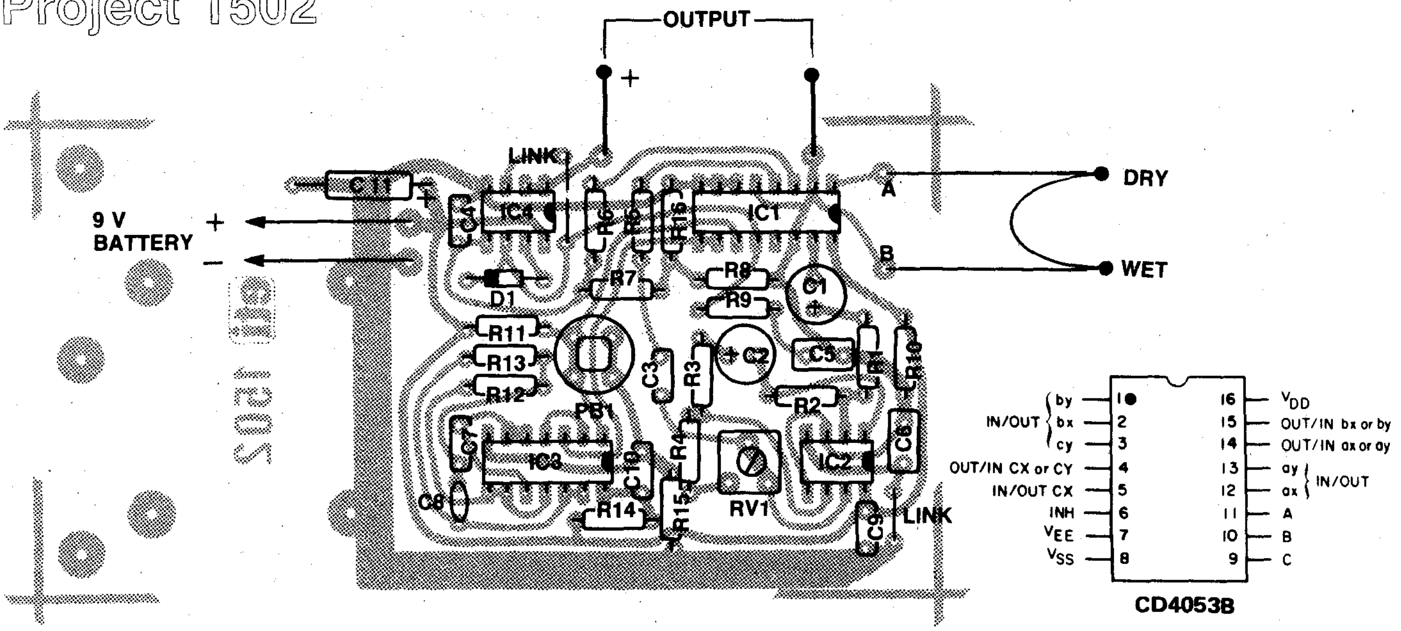
The varying dc voltage is connected to the non-inverting input of the op-amp, pin 5 and feedback is connected around the op-amp through a low leakage diode, D1. When the non-inverting input (pin 5) moves more positive the op-amp output also moves positive and charges C5 to the same voltage. If pin 5 moves slightly more negative, then the output also swings negative and reverse biases the diode. In fact, the op-amp output immediately swings to ground as the diode breaks the feedback loop. Capacitor C5 therefore holds exactly the peak dc voltage that is applied to the non-inverting input to the op-amp. R9 is in series with C5 so, once again, the op-amp output does not have to drive directly onto a large capacitor (if it is left out the op-amp will oscillate when the diode is turned on and the peak detector accuracy falls to pieces). The second op-amp of IC3 is used as a very high impedance input unity gain buffer.

The peak dc voltage is only held as a charge on a capacitor so, in order to be able to take measurements with any voltmeter, the capacitor voltage must be buffered. It is very important to use FET-input op-amps for this part of the circuit and MOSFET input op-amps such as the RCA CA3240 are about the best cheap ones available.

As the voltage on C5 can only go more positive, a way is needed to reset the peak detector when the reading has been taken. The last section of the analogue switch is used as a reset circuit. The common input to the analogue switch is connected to the reference voltage and the input which is off. When the control line is high it is connected to C5. The control line is pulled high by R11 and the analogue switch is off when measurements are being taken. When the reset switch, SW1 is operated C5 is shorted to the reference voltage and at the same time the filter capacitor C4 is allowed to discharge through R7 and R16. The oscillator driving the two synchronous switches is also disabled by SW1 so C4 will not be charged through R6 when the circuit is being reset.

(6) The switch drive oscillator. **The 500 Hz square wave which drives the two synchronous analogue switches is generated by a simple CMOS oscillator formed by IC4, R12 and C7. This circuit is used so commonly that it doesn't really need to be described. Two extra gates, the last of which is also used to gate off the output when the circuit is being reset, square up the drive so the analogue switches are switched cleanly. the whole chopper stabilised amplifier is not sensitive to drive mark-space ratio so no attempt is made to ensure that the drive output is symmetric.**

Resistors R14 and R15, together with C10, filter the supply for IC4, preventing supply rail switching pulses from being coupled into the rest of the circuitry.



Component overlay. Assembly is pretty straightforward. Watch the orientation of the polarised components — diodes, ICs and electrolytic capacitors.

Doing it with wires

The project reads wet bulb depression directly by using a copper-constantan thermocouple to measure the temperature difference between ambient and a junction covered with wet cotton. For the temperature differences we're interested in, the potential difference generated by the thermocouple is a linear function of temperature and is approximately 38.5 microvolts per °C. This gives us our first problem as amplifiers which have input dc offset voltages much less than one microvolt are pretty thin on the ground and usually cost a bomb. The answer to this is to use a chopper-stabilised amplifier so all the gain is produced for ac signals only where offsets are no problem (see How It Works).

The next problem was that the theromocouple responds very fast to temperature changes and stopping whirling the device around and attaching the probes to the amplifier output terminals gave the thermocouple time to change its reading considerably. A simple peak hold circuit had to be incorporated to keep the peak value of the output voltage until it could be read. Even with this peak hold included it was necessary to use a low leakage diode in the peak charging feedback path as diodes such as the old favourite 1N914A have a reverse leakage of about 20 nA at room temperature and this caused the output temperature reading to drift by about 0.1°C per second. (This may not sound like much but it was nigh on impossible to connect the DVM probes and get a good reading in time). The 1N3595 that I used has a reverse leakage of only 1 nA and made things much more manageable but unfortunately the better performance costs — these diodes are not cheap.

Construction

If you are using the artwork supplied then building up the project will give no trouble. First assemble all resistors and capacitors. This is a good general rule when using CMOS integrated circuits as it makes it harder to zap the IC with static charge. Then insert the integrated circuits, making very sure that they are all in the right way **(everyone harps on this but it's an** embarrasingly easy mistake to make as I can personally testify). The orientation of the two coupling electrolytic capacitors, C1 and C2, is not important as the only dc voltage that ever appears across them is the offset voltage of the operational amplifiers and this voltage is very small and can be of either polarity. It's bending the rules a bit to reverse bias an electro but the 10 mV or so doesn't really matter. The polarity of the power supply filter capacitor C8 *does* matter though, so take care.

After all the components except the pushbutton PB1 have been inserted and nearly soldered, it is necessary to thoroughly clean and deflux the board. Parts of the circuit (mainly the node connecting I0C3 pins 3 and 6 to C5, D1 and IC1 pin 12) are very sensitive to leakage and if dirt or flux is left on the board you will waste the money you spent on the 1N3595. The best way to thoroughly deflux the board is to use an el-cheapo 25 mm paint brush, whose bristles have been cut to about 10 mm long, and acetone solvent. Both can be purchased at the local hardware store.

Tip some of the acetone out into a shallow *glass* dish (if you use a plastic dish its bottom will immediately dissolve and you will have acetone everywhere dissolving everything in sight — it's a very good solvent!) and thoroughly wet the short bristles of the brush. Scrub the soldered side of the board and immediately mop the board dry with a clean rag or paper towel. The board must be patted dry as if you try to wipe it the towel will catch on all the cropped component leads but it is important that the board be dried off completely and quickly as if the acetone is left to dry on the board the dissolved flux will be deposited on the board again and can be seen as a white deposit, usually in the spaces between tracks and IC pins. Repeat the scrubbing and mopping dry until the board appears completely clean when the acetone is dried off completely (this usually takes several applications).

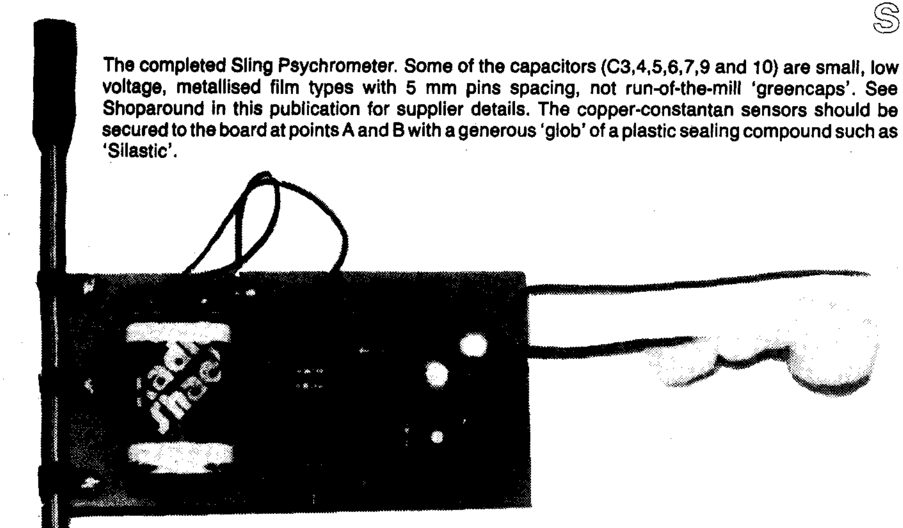
PARTS LIST — ETI-1502

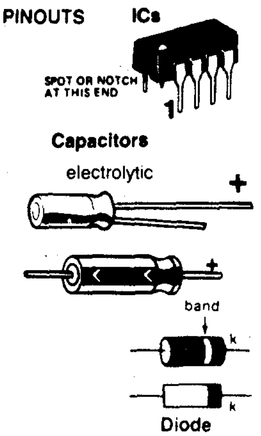
Resistors	all ½W, 5% unless noted
R1, R3	2k20, 0.4W, 2% metal film
R2	120k 0.4W, 2% metal film
R4	100k 0.4W, 2% metal film
R5	4k7
R6	39k
R7, R13	1M0 ¼W, 10% carbon film
R8	150R
R9, R14, R15	39R
R10	15k
R11	100k
R12	56k
RV1	20k cermet trimpot, Allen-Bradley type E or similar.
Capacitors	
C1, C2	47µ/10 V electro, radial leads
C3, 4, 9, 10	100n/63 V metallised film, Wima type RS-21 or similar
C5, C6	1µ/50 V metallised film, Wima type RS-21 or similar
C7	10n/63 V metallised film, Wima type RS-21 or similar
C8	10p ceramic
C11	39µ/10 V electro, axial leads
Semiconductors	
D1	1N3595
IC1	4053B
IC2, IC3	CA3240E
IC4	4011B

Miscellaneous

ETI-1502 pc board; length of copper-constantan thermocouple (about 150 mm); Spintate nut driver (with 4" or 5" shaft); small cable clamps (5 mm i.d. or to suit Spintate shaft); battery snap and battery clamp for No. 216 9 V battery; No. 216 9 V battery, piece of cotton wool.

The completed Sling Psychrometer. Some of the capacitors (C3,4,5,6,7,9 and 10) are small, low voltage, metallised film types with 5 mm pins spacing, not run-of-the-mill 'greencaps'. See Shoparound in this publication for supplier details. The copper-constantan sensors should be secured to the board at points A and B with a generous 'glob' of a plastic sealing compound such as 'Silastic'.





Do this out in the open or in a well-ventilated room. Acetone is flammable, so do not smoke or have anyone smoking nearby while you're doing it and keep away from possible arcs and sparks. Avoid getting the acetone on your skin.

The pushbutton can be soldered in when defluxing is finished. If you insert the switch before cleaning the board there is a very good chance that some flux will be deposited in the contacts and give unreliable operation.

The next step is to attach the thermocouple wire. I used standard copper-constantan insulated thermocouple wire that is available from most scientific supply houses (i.e: Selby Scientific). Only about 150 mm of the pair is needed for the psychrometer, but if you want to use the project for remote temperature sensing as discussed later, much longer runs can be attached with no ill effects.

To prepare the short thermocouple as shown in the photograph, first take about 150 mm of the pair and bare both ends of both wires for about 10 mm. Then lay the pair flat on the table and very carefully trace the *copper* wire back to the centre of the pair. Separate the two insulated wires for about 10 to 15 mm from the centre and cut the copper wire (if you cut the constantan wire you've ruined it). Bare the two ends of the copper wire that you've just cut for about 5 mm and solder them into the printed circuit board. The insulated constantan wire should form a neat loop between the two terminated copper wires. Then twist the two outer pairs of the thermocouple together to form the two junctions.

You should now be able to trace a continuous circuit from one terminal pad on the board through a copper wire to a copper-constantan junction then through the constantan wire back through the loop of wire and through the second constantan-copper junction. The circuit should then continue as copper back to the other terminal pad on the board. If this is all OK then solder both thermocouple junctions neatly with no excess solder. In this circuit it is not important about the solder used as the thermocouple is to be calibrated later, but if the thermocouple was to be used directly into a meter then care would have to be taken to use the same solder for both junctions.

All that remains now is to solder in the battery clip-lead and the circuit is ready for test and calibration.

Amplifier calibration

To calibrate the thermocouple-amplifier combination you will need two kitchen drinking glasses, some ice from the freezer and a reasonably good thermometer. While thermometers expounding the virtues of Bert's Big Ends or Clives Clutches are all good and fine in their place they really aren't accurate enough here. I bought a −10° to +510°C mercury-in-glass thermometer from Selby Scientific at North Ryde (Sydney, NSW) but most scientific supply houses stock them (see your local 'phone book). The thermometer is also used when actual humidity readings are taken and you will find it quite useful round the house as well, and I found the $8.40 really well spent.

Calibration is done by establishing an exactly known temperature difference between the two junctions of the thermocouple and adjusting RV1 until the voltage difference at the output terminals reads correctly. The cold junction is set to 0°C by immersing it in water with plenty of ice in it and the hot junction is immersed in ordinary tap water.

The temperature of the hot junction must be between 18°C and 20°C to give accurate calibration and if the water out of the tap is hotter or colder than this a judicious admixture of ice or hot water will be necessary. Fill one of the tumblers with ice from the freezer then fill it up with water to create a 0°C reference and fill the other glass with water mixed as described. If you have no faith you can check that the ice-water mixture is really at 0°C (alternatively, this could be considered to be a check on your thermometer). Then measure the temperature of the warmer water and note it down. Make sure that the thermometer is left in the water long enough for the reading to stabilise (60 seconds or so is long enough).

Connect the battery to the amplifier and, as a quick check to make sure that all is working, your DVM to the output terminals. If you hold the hot junction with your fingers the output voltage should climb to about 0.5 V in a few seconds (unless it's a very hot day in which case your fingers may actually be cooler than ambient). This test just measures the temperature difference between your fingers and the air temperature and ensures that the amplifier is working correctly.

When the hot junction (the junction whose copper side connects to pin 1 of IC1) is released the output voltage should *very* slowly drift towards zero. In the prototype, the drift was about 1 mV every two or three seconds but if you used a 1N914 in place of the 1N3595 the drift will probably be about 20 mV per second.

After you are satisfied that the amplifier and peak hold circuit are working OK, press PB1 and make sure that the output voltage goes to zero. There will be a slight residual offset due to the input offset voltages of the two op-amps of IC3 but if the output is within ±20 mV of zero all is well.

The final step is to adjust RV1. Place the two tumblers of water that you've prepared close side by side and immerse the hot juntion in the warmer water and the cold junction in the iced water. Both junctions should be about 20 mm below the surface. The DVM reading should rapidly climb to about 1.8 to 2.0 volts. Adjust RV1 fully clockwise to set the amplifier to its lowest gain and operate the zero switch for a few seconds to start adjustment from the lowest voltage. Then, slowly adjust the potentiometer until the output voltage equals the thermometer reading (2.000 volts = 20.00°C). If you overshoot the desired reading and want to come back, then you must operate the zeroing switch after every clockwise adjustment because the peak hold circuit will not allow a gain reduction to be displayed. Make sure that the cold junction is right in the middle of the ice in the tumbler and not at the bottom of the glass as the water at the bottom is probably not at 0°C.

It is a good idea to check this adjustment several times as a 1°C error by misplacing the two junctions in the tumblers or incorrectly measuring the temperature of the hot junction is easy to make and gives a 5% error. Once this adjustment is made the psychrometer is ready to be assembled onto its sling handle. ▶

WET BULB DEPRESSION (DEGREES CELSIUS)

DRY BULB TEMPERATURE (DEGREES CELSIUS)

	0.0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.0	7.2	7.4	7.6	7.8	8.0	8.2	8.4	8.6	8.8	9.0	9.2	9.4	9.6	9.8	10.0
50	100	99	98	97	96	95	94	93	91	90	89	88	87	86	85	84	83	82	82	81	80	79	78	77	76	75	74	73	72	71	71	70	69	68	67	66	66	65	65	64	63	62	61	61	60	59	58	57	57	56	55	54
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18	100	98	96	94	92	91	89	87	85	83	82	80	78	76	75	73	71	70	68	66	65	63	61	60	58	56	55	53	52	50	49	47	46	44	43	41	41	40	38	37	35	34	32	31	29	28	27	25	24	22	21	20
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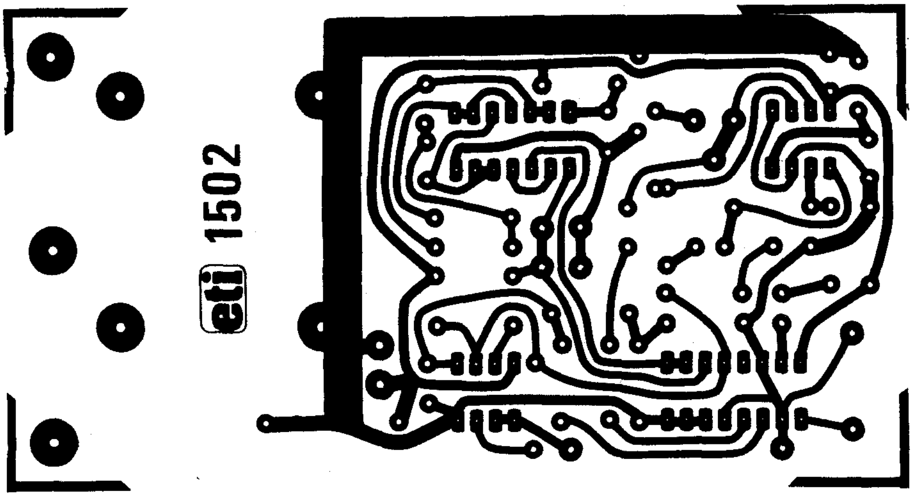
TABLE FOR DETERMINING RELATIVE HUMIDITY

For use at elevations between mean sea level and 250 metres. This table has been constructed from publication #EC87 of the Commonwealth Bureau of Meteorology. This publication, *obtainable from* Bureau offices (see your 'phone directory), contains three tables covering various temperature ranges and wet bulb depression ranges to suit differing climates. The table here covers the generally useful range of condtiions likely to be encountered locally.



Printed circuit. Full-sized artwork for the printed circuit board.

Tie the battery down to the printed circuit board with twist ties (the things you use to close garbage bags) as firmly as possible as it would be most embarrasing to sling the battery through a window, and mount the whole assembly on a suitable handle. I used a spare 'Spintite' nut driver that I had or you could use a screwdriver but make sure that the tip of the spintite is bigger than the clamps that you use to attach the board to the handle (it would be just as embarrasing to sling the whole lot through a window).

Mount the board to the handle using three 'P' cable clamps and the three holes marked on the board so the board can rotate freely around the shaft of the handle. Wrap a piece of cotton wool around the cold junction of the thermocouple and tie it on securely with cotton thread. It is a good idea to bend the last 5 mm of the thermocouple wire back on itself and bury it in the cotton wool to make sure that it remains covered at all times with the wool. You sling psychrometer is now ready to try out.

Making measurements

In order to take a humidity reading, the first thing to do is wet the cotton wool around the cold junction. Drip tap water on the cotton wool until it is thoroughly wet but not completely dripping. You must be extremely careful not to get any water on the board itself as you've spent a lot of money on low leakage diodes and water would not improve the leakage properties of the board surface one little bit. Allow the wet cotton wool to stand a while to allow the water to reach room temperature, five minutes or so should be enough, then connect the battery and whirl the psychrometer around in the air for 60 seconds or so.

If you had too much water on the cotton wool this will get rid of it most effectively and at the same time creates the necessary draft over the wet wool to cool the cold junction of the psychrometer. After it has been spun for the required time place the psychrometer on an insulating surface (a formica tabletop for instance) taking great care not to touch the back of the board at all and connect your DVM to the two output terminals.

The *wet bulb depression temperature* can be read off directly by multiplying the volts by 10 and calling them degrees Celsius. Next, measure the actual air temperature with the accurate thermometer used to calibrate the amplifier. Finally, look up the tables given at the end of this article to determine the actual relative humidity.

First use the air temperature to find the correct row in the tables then use the psychrometer reading to find the column which has the actual humidity value. As an example, I took a reading and found that the air temperature was 23.7°C and the wet bulb depression from the psychrometer was 7.63°C (it is interesting to note that the electronic psychrometer is a great deal more accurate than the normal wet and dry bulb so we must round the wet bulb depression reading off to 0.2°C). Rounding the temperature off to the nearest degree gives an ambient temperature of 24°C and rounding the wet bulb depression off gives 7.6°C.

Referring to the tables we have a row of humidity values which start with 49% on the left (wet bulb depression = 7.0°C) and go to 10% for a wet bulb depression of 14.0°C on the right. The fourth value in from the left corresponds to our wet bulb depression of 7.6°C and gives the result of 46%. As is always the case when using tables to work anything out it is not possible to find the exact value, but even so the humidity readings obtained this way are accurate to about 1% (*if* you calibrated the amplifier accurately!).

As a thermocouple amplifier

The psychrometer can also be used as a straightforward thermocouple amplifier to measure temperature in differences from ambient temperature. The peak hold function can be left in, or removed in the following way. First remove C5 and R9 then replace D1 with a piece of wire. This converts the op-amp IC3 pins 5,6 and 7 to the simple unity gain buffer and allows the amplifier output to follow temperature differences continuously. The thermocouple wire connected to the amplifier input can be as long as necessary to monitor the desired temperatures, but as there is no input filtering care should be taken to avoid gains hum pickup.

If the wire is very long and you want the reference temperature to be the ambient then it is not necessary to have both thermocouple junctions remote from the amplifier. Simply use a length of copper-constantan wire pair with one end of the pair bared and twisted together to form a junction and the other end of the pair bared and soldered onto the two amplifier input terminals. The terminal where the constantan wire is soldered onto the board becomes the second junction of the thermocouple and temperature differences are measured from the temperature of this connection.

Calibration of the amplifier is a bit more complicated in this case as you can't very well immerse the whole amplifier in a glass of water to establish a reference temperature. I calibrated the setup in the following way. First power up the amplifier and connect the DVM to the output terminals. Make up a 0°C reference again with ice and water in a tumbler as was done to calibrate the psychrometer and immerse the sensing junction in it (once again, make sure that the junction is right in the middle of the ice and not at the bottom of the tumbler). Rest the mercury-in-glass thermometer on the amplifier and leave the whole lot to stabilise for 15 minutes or so. The amplifier should be away from any draughts or direct sunlight as the thermometer is supposed to measure the temperature of the printed circuit board and any outside sources of heat or cold will create temperature gradients which will destroy the accuracy of the reading.

When everything appears to have settled down adjust RV1 until the amplifier output reads the same as the mercury-in-glass thermometer. As the peak hold circuit is no longer functioning you can adjust either way with no trouble. As the sensing junction is at 0°C the temperature difference for the thermocouple is the temperature of the board (and reference junction) directly. If you want to reverse the polarity of the output readings then reverse the two thermocouple wires connected to the amplifier input; both input terminal pads and copper and the amplifier will work just as well.

Temperature adaptor for your multimeter

This simple add-on project extends the functions of your multimeter to the measurement of temperature. It is particularly suited to digital multimeters. It can be used to measure temperature over the range from −55°C to +150°C with an accuracy of 0.5°C or better.

Geoff Nicholls

IT IS SURPRISING how useful an 'electronic thermometer' can be in an electronics workshop or laboratory. Temperature measurement is a rarely-included function on modern multimeters, however. Measuring temperature in a chemistry or physics lab is commonplace, and the same should be so in an electronics lab, but rarely is.

Component temperature rise, or the actual operating temperature of a device, can be an important parameter in a circuit — no matter whether the component's a resistor or a transistor. The performance of heatsinks can be assessed using temperature measurements.

When fault-finding or servicing equipment, thermal problems can be quickly sought out and identified by temperature measurement. And that's just a few applications!

Sensors

There are a number of ways to measure temperature electrically or electronically. Thermocouples, which consist of two dissimilar metal wires bonded together, have long been used. The junction of the metals generates a small voltage that is proportional to the junction temperature. The voltage output is non-linear with changing temperature. Thermocouples are generally used for temperature measurement at high temperatures and over extremely wide ranges.

The resistance of semiconductor material varies considerably with temperature and this is exploited in 'thermistors'. The variation is non-linear, but thermistors have been used for temperature measurement where accuracy and linearity are not important.

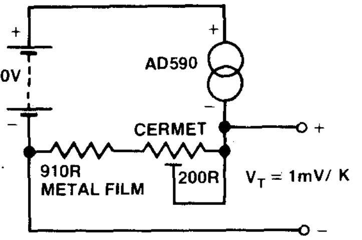


Figure 1. Simple thermometer with +/− 2 C accuracy.

Any semiconductor junction will exhibit temperature dependence of the forward conduction voltage. For silicon junctions, which have a forward conduction voltage of around 600 mV, the junction voltage will vary by typically −2.2 mV/°C at a forward current of around 250 uA, and this is generally linear over quite a wide range.

Silicon diodes and the base-emitter junction of silicon transistors are often used in temperature sensing and control applications. Accuracy and repeatability are generally very good. We described a digital temperature meter which employed a silicon diode sensor (ETI-589) back in the December 1977 issue.

However, a number of specially-constructed ICs are available which have been designed to provide a highly accurate and linear temperature-to-current or temperature-to-voltage output over a wide temperature range. Such devices are unrivalled for accuracy, linearity and speed of response.

I chose the Analog Devices' AD590 which is available in two package styles — a TO-52 'can' and a tiny ceramic flat pack — and several accuracy grades. It is distributed by Parameters Pty Ltd, 41 Herbert St, Artarmon NSW 2064. (02)439-3288.

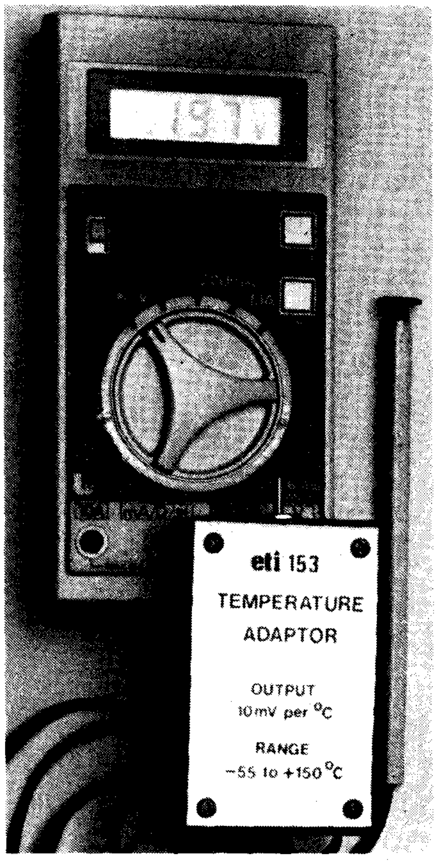
The AD590

The AD590 is a two-terminal integrated circuit temperature transducer which produces an output current proportional to absolute temperature. For supply voltages between +4 V and +30 V the device acts as a high impedance, constant current regulator passing 1 uA/°K. Laser trimming of the chip's thin film resistors is used to calibrate the device to 298.2 uA output at 298.2°K (+25°C).

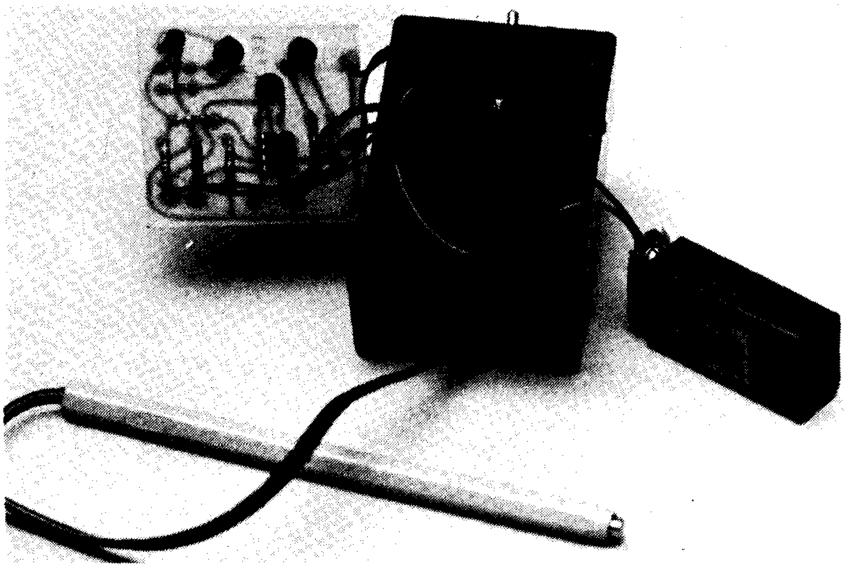
The device is particularly useful in remote sensing applications. The device is insensitive to voltage drops over long lines due to its high impedance current output. Any well-insulated twisted pair is sufficient for operation hundreds of feet from the receiving circuitry.

Superior interference rejection results from the output being a current rather than a voltage. In addition, power requirements are low (1.5 mWs @ 5 V @ +25°C), making the AD590 easy to apply as a remote sensor. The high output impedance (>10M) provides excellent rejection of supply voltage drift and ripple.

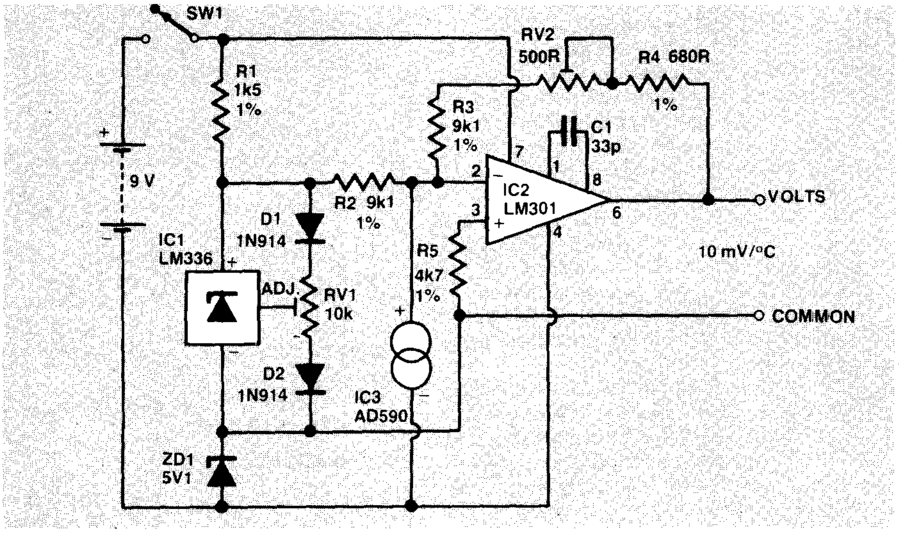
It is electrically durable, withstanding a forward voltage up to 44 V and a reverse voltage of 20 V. Hence, supply irregularities or pin reversal will not damage the device.



And it's 19.7°C! Our adaptor plugged into one of the lab. multimeters.



Simplicity. Construction is quite simple and all the electronics fits neatly in a small jiffy box. The tops of the banana plugs can just be seen. These are spaced at 19 mm ('GR' spacing) or to suit your multimeter input sockets spacing.



HOW IT WORKS — ETI-153

The AD590 temperature transducer, IC3, requires a voltage to be applied across it, developing a current that is directly proportional to absolute temperature with a precision sensitivity of 1 uA/°K. This is amplified by an op-amp, employed here as a current-to-voltage converter that provides an output of 10 mV/°C. As zero Kelvin is 273 degrees below zero Celsius, an 'offset' has to be provided for the output to be proportional to the Celsius scale. This is achieved by running the op-amp input at 'virtual ground' and supplying the AD590 sensor from a negative supply rail. Thus, at 0°C, the output will 0 V.

IC1 is a precision voltage reference (LM336) that maintains 2.49 V between its +ve and −ve pins. Two silicon diodes, D1 and D2, and a cermet (high stability) trimpot, RV1, allow the reference voltage to be 'trimmed'. This is normally done to minimise the temperature coefficient of the LM336, however, I have used it to provide trimming of the offset of Celsius zero from absolute zero.

Zener diode D3 provides a negative supply rail for the AD590 temperature transducer (IC3). The voltage obtained is around −4.5 V as the 5V1 zener is operated at a current of about 1 mA, set by the value of R1. The zener in the prototype was rated at 400 mW. If a 1 W type is used, R1 should be reduced to 1k.

IC2 is used in 'virtual ground' mode as a current-to-voltage converter. Its operation can be understood by remembering that IC2 is an op-amp and to a good approximation has infinite gain and infinite input impedance. A negative feedback path, formed by R3-R4-RV2, acts to maintain the inverting input (pin 2) at the same potential as the non-inverting input (pin 3). i.e: at 0 volts. Although very little current flows into pin 2 of IC2, it is kept at 0 V by the feedback action.

The AD590 connects to pin 2 of IC2 (inverting input) and acts as a current sink, passing 1 uA/ K. The reference, IC1, supplies a current of 273 uA through R2, which can be trimmed by RV1. Thus, the current through the feedback resistors is equal to the absolute temperature minus 273, in microamps, and results in an output voltage of 10 mV/°C when RV2 is set to provide the 'scale factor' required.

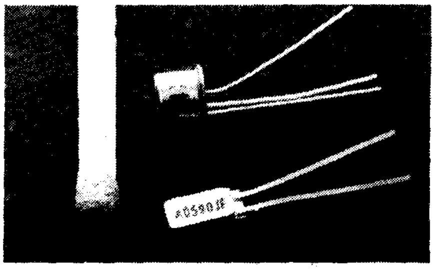
To ensure the appropriate accuracy, high stability 1% metal film resistors and cermet trimpots are used. Capacitor C1 provides compensation for the op-amp, to ensure stability.

The AD590 is available in a number of accuracy grades. The 'M grade' device will give better than ±0.05° accuracy from 0° to 100° Celsius. It costs around $60, however. For about $5, you can purchase the 'J grade' AD590 which will give an accuracy of ±0.3° from 0° to 100°C. The accuracy you get depends on a number of factors (discussed later) and the type of circuit.

The simplest circuit you could use is shown in Figure 1. This will give temperature directly in the Kelvin scale with a voltage/temperature relationship of 1 mV/°K. Thus at a typical ambient temperature of +25°C (298°K), the output will be 0.298 V. The output can be 'trimmed' to the correct temperature (calibrated) at one temperature point by the 200 ohm cermet trimpot. This is a 'one trim' circuit. With the AD590J, accuracy will be ±2° over the range from 0° to 100°C.

A circuit which provides for two trim, or calibration, points results in much better accuracy, Also, a more convenient voltage/temperature relationship is useful, which requires the output of the sensor to be scaled. An op-amp can be used for this to provide a stable gain. A figure of 10 mV/°C (or /°K) is suitable, and that's what I chose.

The accompanying photograph shows the two package styles compared to a match head. The TO-52 can (H package) is for general use. It has a longer time constant — the time taken to stabilise after changing the package's temperature — than the ceramic flat pack (F package). Typically, the H package will take four minutes to stabilise in still air, but the F package will only take about half that time. When applied to an aluminium block (e.g: a heatsink), the H package will typically take four seconds to stabilise, while the F package will take around half a second.



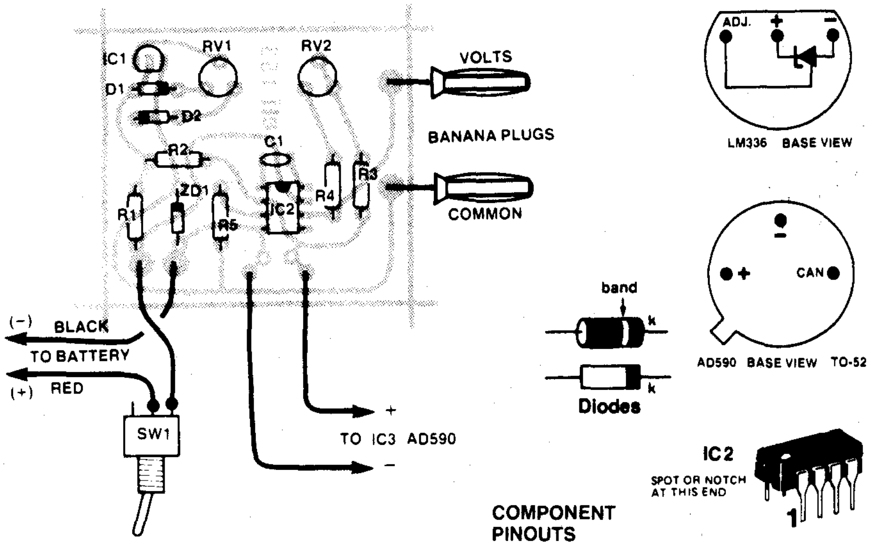
Tiny, what? The two versions of the AD590 packaging, compared to a match head. Above is the H package (TO-52); below is the ceramic F package.

Construction

The project was designed to fit inside a small jiffy box with a metal lid having overall dimensions of 30 x 50 x 80 mm. They're common and low in cost.

All the electronics, except the AD590 sensor, are mounted on a small pc board. This can be assembled first. Just check your pc board before assembling the components, ensuring there are no broken tracks or shorts between tracks and that all holes are correctly drilled.

The components can be assembled to the pc board in any order, just watch that you put the two ICs, the two diodes and the zener the right way round. Don't take too long to solder the resistors as they are high stability types, but ensure that each joint is properly made. ▶



COMPONENT PINOUTS

I mounted the banana plugs in the box between the plastic pillars at one end so that the whole unit plugged straight into a normal multimeter. To do this, the plugs must be spaced ¾" (19 mm) which is known as 'GR' spacing. To make this easier, I have laid out the pc board with the output pads spaced exactly at 'GR' spacing. The board can be used as a template when drilling the holes for the banana plugs.

Remove the plastic body of each plug and solder about 10 cm of insulated hook-up wire to each. Using the pc board, drill pilot holes of about 1 mm diameter through the box near one end and enlarge them until the banana plugs will fit through the box.

Cut the plastic body of each plug in half and install the plugs, tightening the body from the inside for each plug.

Drill a hole for the switch, between the plugs, in the end of the box making sure that the switch will not foul the plugs.

If the switch you have will not mount as mine did then you may fit it into the lid of the box, but keep it near the end where the plugs are.

Also drill a hole, in the end of the box opposite the switch, for the cable from the sensor.

Wire up the battery connector, switch and plugs, following the overlay. Don't connect the AD590 yet. Plug the unit into your multimeter, set RV2 to the mid-position and set you multimeter to the 20 V range. Switch on and adjust RV1 to obtain a reading of −2.73 V.

The probe

I made the probe from the barrel of a BIC 'finepoint' pen. Discard the innards and cut back the pointed end by about 2 mm. Use a 7/32" drill bit to carefully enlarge the hole at the pointed end to a depth of 2 mm.

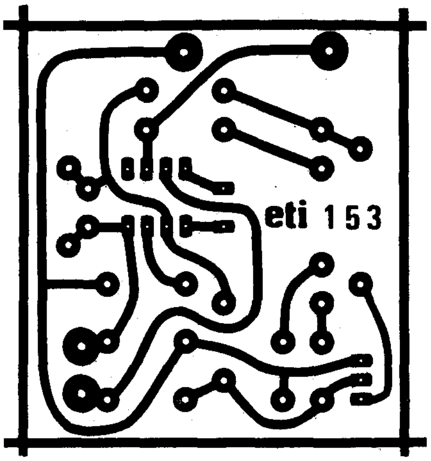
Cut the −ve lead of the AD590 back about 6-7 mm. This identifies the two leads. Now snip the tab off the AD590 and file the tab stump back to allow the device to slip into the pointed end of the modified pen barrel.

The lead between the sensor and the electronics is a convenient length of small figure-8 flex with one marked lead (i.e: 'light speaker wire'). I used a length about one metre long. Slip one end through the pen barrel and trim back the unmarked lead by about 6 mm. Solder the marked lead to the AD590 +ve lead, the unmarked (cut back) lead to the AD590 −ve lead.

It is important to keep moisture away from any exposed conductors, since only one microamp of leakage will cause a one degree error. Consequently, after soldering I coated all exposed conductors and the base of the AD590 with two coats of nail polish, allowing drying time between coats.

Now seal the AD590 into the end of the pen barrel. I used a silicone sealant ('Silastic'), poking some down the pen barrel, in the pointed end first, then putting a blob on the base of the AD590 before pushing it in place. Wipe away any excess. Put a blob down the other end of the barrel, too.

Take the free end of the cable, strip and tin the two wires. Pass this end through the hole you drilled in the box for it and knot the cable on the inside leaving about 60 mm to the end. Solder the two wires to the pc board as per the overlay. Remember, the marked lead is from the +ve of the AD590.



Artwork. Full size artwork for the pc board and front panel. You can obtain a 1:1 negative or positive, for making your own pc board and/or Scotchcal, for $1.00 each, post paid, ($2.00 the pair) from **ETI-153 Artwork, ETI Magazine, P.O. Box 21, Waterloo NSW 2017.** Make your cheque or money order out to 'ETI Artwork Sales'. Ensure you ask for a **positive** or **negative**, as you require.

PARTS LIST — ETI 153

Resistors	all 1% metal film, unless noted
R1	1k5
R2, R3	9k1
R4	680R
R5	4k7
RV1	10k cermet, horizontal pc mount trimpot
RV2	500R cermet, horizontal pc mount trimpot
Capacitor	
C1	33p ceramic
Semiconductors	
IC1	LM336 precision voltage reference
IC2	uA301, LM301 gen. purp. op-amp
IC3	AD590J precision temp. sensor (see text)
D1, D2	1N914 or 1N4148
ZD1	5V1, 400 mW zener (see note).

Miscellaneous
ETI-153 pc board; UB5 zippy box (28 x 54 x 83 mm); two banana plugs; hookup wire, cable, probe etc.

NOTE: A 5V6/1 W zener may be used but, if so, change R1 to 1k.

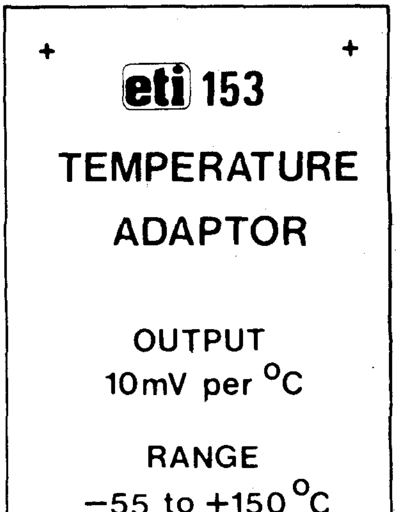
Price estimate $18 — $20

Switch the unit on and set the multimeter to the 2 Vdc range (unless it's an auto-ranging meter). You should get a reading of around 0.200-0.250 or so, depending on the ambient temperature. If not, reverse the leads from the AD590 and try again. If you still get no result, there's a fault which you'll have to track down and correct.

If all's well, you can now calibrate the unit for maximum accuracy.

Calibration

There are three main methods of calibration; I shall describe them in order of increasing



accuracy.

The simplest way is to leave RV2 set in the mid-position and adjust RV1 to read a known temperature. This requires a thermometer to be placed in the same thermal environment as the AD590 sensor. This method will result in accurate readings over a range of 10 to 20 degrees, depending on the resolution of the reference thermometer.

The second calibration technique involves adjusting RV1 to obtain a reading at 0°C with the sensor immersed in melting ice, then placing the sensor in steam and adjusting RV2 for a reading at 100°C.

For this method, a good ice bath is a tall glass (but a vacuum 'Thermos' flask is better) filled with pure crushed ice which is then allowed to melt until the liquid level about two-thirds fills the glass.

Place the sensor about 20 mm below the water surface, wait for the multimeter reading to stabilise, then adjust RV1 to obtain a reading of 0.000 V.

Next, surreptitiously borrow a small saucepan from the kitchen and half an hour of kitchen time. Boil up a litre or two of water so that it's boiling rapidly with plenty of steam emitting. Place the sensor in the steam cloud, allow a few seconds for the reading to stabilise, then adjust RV2 for a reading of 1.000 V. Note that the boiling point of water depends on altitude so this method is strictly only accurate at or near sea level, unless you can borrow a reference thermometer of sufficient accuracy.

The most accurate calibration is obtained by using a laboratory grade thermometer and immersing it and the AD590 in a stirred liquid bath — first one bath at a temperature low in the desired range, then in another at a temperature high in the range. For best accuracy, you need to repeat the procedure several times, adjusting RV1 at the lower temperature and RV2 at the higher temperature, until the desired accuracy is reached.

With the calibration completed, you can complete the assembly. Cut a rectangle of thin cardboard the same size as the box lid, then cut off the corners. The pc board goes in the box with the components facing down, the battery going in first. The cardboard goes between the copper side of the pc board and the lid, preventing shorts.

I dressed up the box lid with a Scotchcal label. If you want to do the same, apply the Scotchcal to the lid before screwing it to the box. Peel off the backing at one end and carefully align it against the edge of the panel. Smooth it down and then continue peeling off the backing, smoothing the label in place as you go. Any air bubbles can be removed by rubbing them towards the nearest edge.

That's it!

For improved thermal coupling under some circumstance, a small heatsink can be slipped over the AD590. I used a Thermalloy No. 2224B. Note that this slows down the thermal response. When measuring the temperature of solid objects, particular metal objects (transistor cases, heatsinks, resistor bodies, etc), use a little thermal paste to improve thermal coupling. ●

ACCURACY

The overall accuracy of the ETI-153 is determined by three main factors: (i) *calibration error and overall accuracy* of the AD590 sensor; (ii) the *thermal environment* in which it is used, and (iii) *drift in the electronics* due to changes in the ambient temperature.

1. Calibration error and non-linearity of the AD590. This factor is easily calculated by referring to the table from the Analogue Devices applications note (Table 1), reproduced here. The 'Number of Trims' column refers to the type of circuit used with the AD590J. For the ETI-153, use the 'Two Trims' data. For the simple Kelvin circuit (Figure 1) use the 'One Trim' data.

To obtain the error after calibrating at 0°C and 100°C, look down the row where the temperature span is 100°C until you find the column under 0°C, which is the lowest temperature in the span. The error is found to be ±0.3°C. If you calibrate the instrument at 0°C and 50°C, the error is ±0.1°C. These figures exclude any trim errors due to the calibration technique, of course.

J GRADE Number Of Trims	Temperature Span (°C)	Lowest Temperature In Span (°C) -55	-25	0	+25	+50	+75	+100	+125
None	10	4.2	4.6	5.0	5.4	5.8	6.2	6.6	7.2
None	25	5.0	5.2	5.5	5.9	6.0	6.9	7.5	8.0
None	50	6.5	6.5	6.4	6.9	7.3	8.2	9.0	–
None	100	7.7	8.0	8.3	8.7	9.4	–	–	–
None	150	9.2	9.5	9.6	–	–	–	–	–
None	205	10.0	–	–	–	–	–	–	–
One	10	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.3
One	25	0.9	0.6	0.5	0.5	0.5	0.6	0.8	0.9
One	50	1.9	1.5	1.0	1.0	1.0	1.5	1.9	–
One	100	2.3	2.2	2.0	2.0	2.3	–	–	–
One	150	2.5	2.4	2.5	–	–	–	–	–
One	205	3.0	–	–	–	–	–	–	–
Two	10	0.1	*	*	*	*	*	*	0.1
Two	25	0.2	0.1	*	*	*	*	0.1	0.2
Two	50	0.4	0.2	0.1	*	*	0.1	0.2	*
Two	100	0.7	0.5	0.3	0.7	1.0	–	–	–
Two	150	1.0	0.7	1.2	–	–	–	–	–
Two	205	1.5	–	–	–	–	–	–	–

*Below 0.05°C

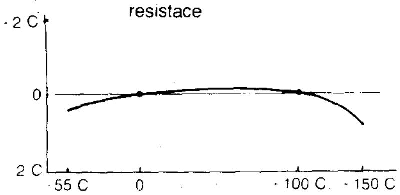
Table 1.

2. Thermal environment. The AD590 dissipates a tiny amount of power owing to the voltage across it and the current flowing through it. This power causes self-heating of the sensor and must be allowed for so as to obtain maximum accuracy.

The rise in sensor temperature due to self-heating is given by:

$$T_J - T_A = P(\theta_{JC} + \theta_{CA}).$$

Where T_J is the junction temperature of the AD590.
T_A is the ambient temperature
p is the power dissipated
θ_{JC} is the chip-to-case thermal resistance
θ_{CA} is the case-to-medium thermal resistace



Typical two-trim accuracy.

Typical values of $\theta_{JC} + \theta_{CA}$ are given in Table 2.

Using this information, the temperature rise at 25°C (= 298°K) due to a power dissipation of approximately 298 uA by 4.5 V = 1.3 mW (in still air, without a heatsink), is given by:

$$T_J - T_A = 1.3 \times 10^{-3} \times 480$$
$$= 0.62°C.$$

Note however, that $T_J - T_A$ is directly proportional to the absolute temperature and hence, if the ETI-153 is calibrated with the AD590 in the same medium as it will be used, then the adjustment of the scale factor, with RV2, will compensate for the self-heating effect. In any case, the error is reduced by better thermal coupling to the medium.

The other main environmental effect is the thermal time constant, or the speed of response of the sensor to temperature changes. The column, τ, in Table 2 gives the time required to reach 63.2% of a step temperature change. The response is given by:

$$T(t) = T_{initial} + (T_{final} - T_{initial})(1 - e^{-t/\tau})$$

3. Drift in the electronics due to ambient temperature changes. There are three error terms here. *Thermocouple errors* are introduced by dissimilar metal junctions being at different temperatures. This can only be seen in the AD590 end of the circuit, since all the electronics in the jiffy box can be assumed to be at the same temperature.

Since the AD590 has a power supply rejection of 0.5 uA/V and the maximum possible thermocouple voltage is far less than 20 mV, the effect on the output is negligible.

The electronics in the jiffy box operates at *ambient temperature* which introduces errors when it varies from what it was during calibration of the instrument.

The major contribution to this error comes from the two ICs. Using the worst-case figures for temperature changes over a 0° — 70°C ambient range results in a maximum error of less than 1°C in the output. In practise, the drift from this cause should be much less.

I subjected the prototype to a blast from a hair dryer for about one minute which resulted in a temperature change of 0.1°C. Few multimeters would have better stability than the ETI-153 under these conditions.

Over normal ambient temperature changes ranging from about +15° to +35°, the output change caused by drift in the electronics should not degrade the accuracy of the AD590.

MEDIUM	$\theta_{JC} + \theta_{CA}$ (°C/watt)		τ (sec)	
	H	F	H	F
Aluminium block	30	10	0.6	0.1
Stirred oil	42	60	1.4	0.6
Moving air				
with heatsink	45	—	5.0	—
without heatsink	115	190	13.5	10.0
Still air				
with heatsink	191	—	108	—
without heatsink	480	650	60	30

Table 2

Project 166

A laboratory standard function and pulse generator

Part 1

Here is another of our laboratory standard test equipment projects. This function and pulse generator covers the range from 1 Hz to 1 MHz, generates sine, square, triangle ramp and pulse waveforms. It features digital readout and six output voltage ranges, from 10 V down to 30 mV peak-to-peak. It has positive- and negative-going pulse outputs and the pulse width can be set from one second to 100 ns in seven ranges. In addition, it can be swept by an external sweep generator.

David Tilbrook

APART FROM a good multimeter and a variable, protected power supply or two, every electronics workshop worthy of the title, and every electronics enthusiast of serious intent, *needs* a function generator of some sort with performance adequate for the various tasks the operator is likely to engage in.

Now, that's a pretty vague specification. These days, the 'various tasks' one can tackle might range from amplifier system performance checks to the design and construction of a microprocessor system. At some stage of the task being tackled, a signal source of some description will be a necessity, like as not. I had to set some sort of performance specification when setting out the initial requirements of this project and cast around for a good starting point.

The best starting point I could find was right under my nose: the Wavetek function and pulse generator we've had in the lab here at ETI for some years. Now, Wavetek is to function generators what Tektronix is to oscilloscopes, so I figured our generator was a fair place to start the process.

Our model 166 Wavetek covers 0.0001 Hz to 50 MHz. It has sine, triangle, ramp, square and pulse outputs (TTL level, positive- and negative-going). The function output can be varied from 0 to 30 V peak-to-peak (open-circuit, 15 Vp-p into 50 ohms). The output dc offset can be varied over ±10 V open circuit, ±5 V into 50 ohms. The frequency can be swept over a 1000:1 range, log. or linear. The output can be amplitude modulated and the waveforms can be triggered. On sinewave output, the distortion is less than 0.5% between 10 Hz and 100 kHz, rising outside those limits. The triangle linearity is greater than 99% between 0.005 Hz and 100 kHz.

The pulse output can be triggered, double-triggered, gated or swept. The pulse period is variable between 20 ns and 10 000 seconds while the pulse width is variable between 10 ns and 100 ms in seven ranges. The transition time is variable, too, from 7 ns to 50 ms in seven ranges. The amplitude, dc offset and frequency stability in linear mode (to 500 kHz) is ±0.05% over 10 minutes, ±0.25% over 24 hours.

They are the main performance parameters of the Wavetek 166. It has a circular frequency-setting dial with calibration markings around the skirt. The dial frequency also indicates the start frequency of a sweep range. It has served us extremely well to date. However, quite a few of the performance functions and features have not been needed.

The next question I posed was, what functions and features of the Wavetek could be done without or would not be required by the serious enthusiast or general electronics workshop?

For a start, the frequency range is probably far too wide. I settled on 1 Hz as being a practical lower limit after considerable discussion among staff and associates. This is low enough for a great many *slow* digital operations and in linear applications is good for checking loudspeaker drivers for 'poling', etc. The upper limit, I knew, would be somewhat dictated by the sort of technology I would be restricted to using, given the restraints of component availability and cost. Without looking at the latter too closely, I thought an upper frequency range of 1 MHz was a desirable goal.

GENERAL SPECIFICATIONS — ETI-166 FUNCTION/PULSE GENERATOR

Function outputs	sine triangle square sawtooth
Frequency range	1 Hz to 1 MHz in seven ranges (square to 100 kHz only)
Pulse outputs	positive going } TTL level with pullup to 5 V negative going } (repetition rate set by frequency control, 1 Hz to 1 MHz)
Pulse width range	1 sec. to 100 ns in seven ranges
Frequency display	3½-digit, 1 Hz gate time, 1.000 Hz to 1.000 MHz
Sinewave distortion	typically less than 2% THD; diode shaped
External sweep input	sweeps generator over one-decade range; 1 V peak
Output voltage ranges	10 V, 3 V, 1 V, 300 mV, 100 mV, 30 mV (peak-to-peak)

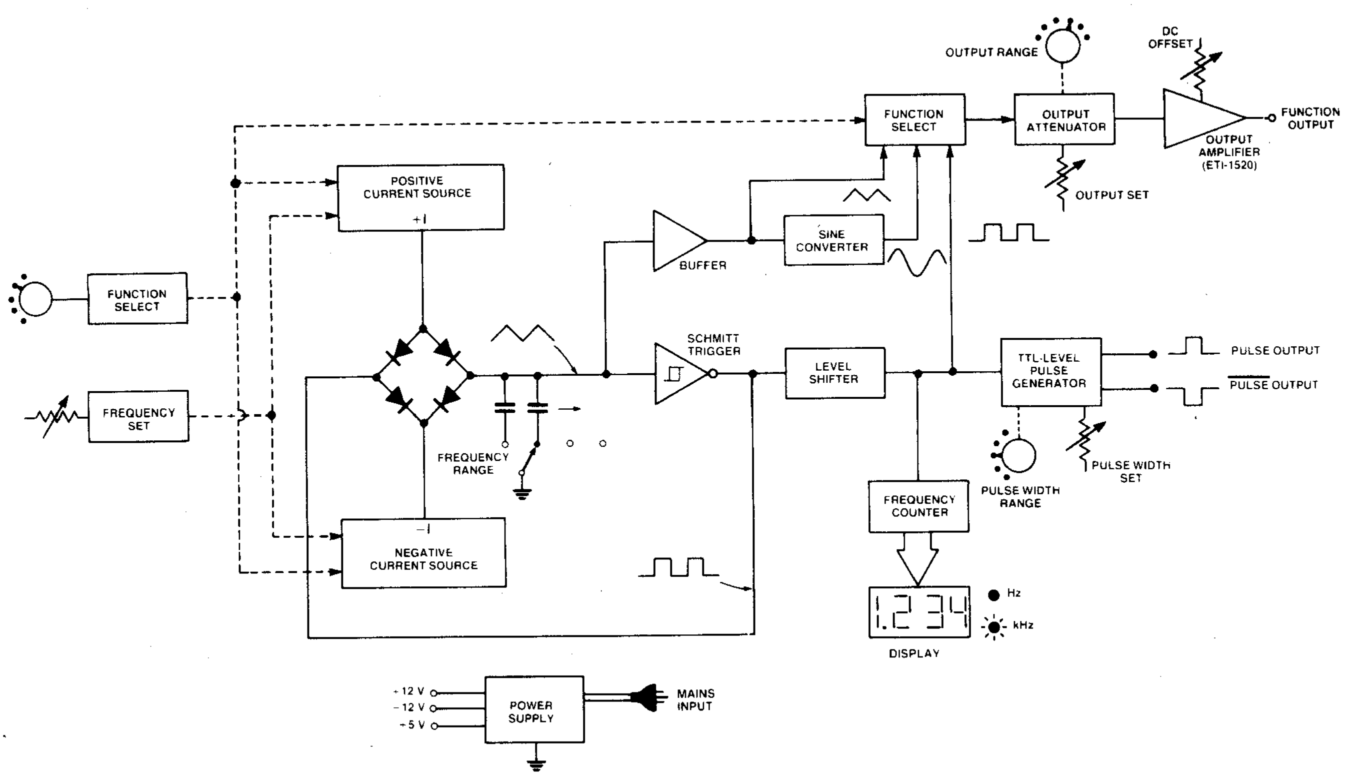


Figure 2. Block diagram of the ETI-166.

Two constant-current sources, **+I** and **−I**, are at the heart of the main oscillator. A diode 'steering' network, **diodes A-B-C-D**, allows **+I** to charge the integrating capacitor and **−I** to discharge it. The frequency range switch selects the integrating capacitor required. The oscillator works like this: let's assume the **Schmitt trigger** output is high (+ve) to start with. Diode D will be reverse-biased and diode C will be forward-biased, reverse-biasing diode B. Diode A is forward-biased and thus the integrating capacitor will be charged by **+I**.

The voltage on the capacitor will rise linearly until it reaches the upper threshold of the Schmitt trigger. The Schmitt's output will then swing negative, reverse-biasing diode C and forward-biasing diode D. This reverse-biases diode A, and diode B will thus be forward-biased, allowing **−I** (a current **sink**) to discharge the capacitor.

The voltage on the capacitor will fall linearly until it reaches the lower threshold of the Schmitt trigger, whose output will then revert to the high state, commencing the process once again.

As the diagram shows, the capacitor voltage is a triangular wave, while the Schmitt trigger output is a square wave.

By varying the actual current sourced and sunk from **+I** and **−I**, the oscillator frequency can be varied. Thus, voltage or current control of the frequency can be incorporated and the **frequency set** control is a potentiometer. To produce a sawtooth wave, the charge and discharge currents have to be different.

For a **ramp-up** wave, the integrating capacitor is discharged quickly by increasing the current sunk by **−I**. For a **ramp-down** wave, the capacitor charge current supplied by **+I** is increased. This is achieved by the **function select** control.

The capacitor voltage signal is buffered and the triangle/sawtooth wave passed to the **function select** module. To produce a **sinewave**, the buffered triangle wave is passed to a **sine converter**, whose output passes to the **function select module**.

The Schmitt trigger output is passed to a **level shifter** so that the square wave signal swings between 0 V and the +ve supply rail. The **frequency counter** takes its input from this point, as does the TTL-level **pulse generator module**. The latter produces complementary pulse outputs with very fast rise and fall times. This employs a TTL monostable multivibrator, a switch selecting appropriate capacitors for the **pulse width range** and a pot. providing **pulse width set**.

The output of the function select module passes to the **output amplifier** via an **attenuator**. The output amp. includes a **dc offset** adjustment that can be varied with a pot.

Sweep-generation circuitry has not been included in the ETI-166, simply because we couldn't fit it in a reasonably-sized off-the-shelf case! Apart from that, we realised that a stand-alone sweep generator could be used with many of the commercially available signal generators so would be suitable as a project in its own right.

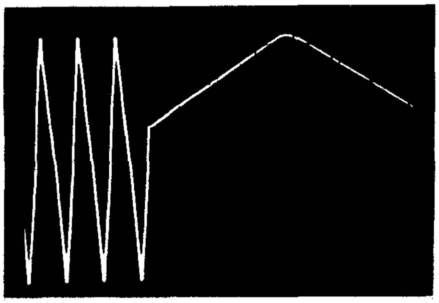
Constructionally, the ETI-166 has been divided into logical modules — the main generator, the frequency counter and display and the output amplifier. The latter has been dubbed Project 1520 and appears elsewhere in this issue.

What about the function outputs? They were obvious: sine, triangle, square, and ramp-up/ramp-down. The pulse outputs were a little trickier. The general consensus was that it would be desirable to set the pulse width over a wide range and that variable transmission time was rarely required. As TTL level outputs with resistive pull-up suit both CMOS and TTL circuitry, TTL level outputs only were settled on. Complementary outputs (negative- and positive-going pulses) were considered to be desirable.

The function output level, and the desirability of dc offset adjustment, came in for much discussion. Should the generator be capable of driving a 50 ohm load at some tens of volts peak-to-peak, or was some other arrangement tolerable and easier to achieve? A search through the data books and a little quick experimentation soon settled the question. The former was certainly possible and considered generally desirable.

The goal was to get a maximum output level of 10 Vp-p into 50 ohms (20 Vp-p open circuit) right across the frequency range — a tall order, because the output stage is required to deliver around a quarter of a watt. In addition, it would need to have a bandwidth of at least five times or more than the frequency range of the generator to accommodate the harmonics that go to make up the non-sinusoidal functions.

The ability to vary the output range between zero and a defined maximum is desirable. The Wavetek has an 'output attenuator' variable in 20 dB steps, but from experience we had found the intervals too great on many occasions so I settled on having 10 dB steps for the output attenuator on this generator. As the dc offset facility had come in handy — particularly when working with digital circuitry — provision had to be made for that, too. Much digital work is done with high-level signals, while much audio work is done with low- and high-level signals, ranging from millivolts to volts. The output attenuator has to cope with those requirements. ▶



A real smoothie. Output of the triangle wave generator at 1 MHz; expanded trace on the right.

Then came *sweep.* The ability to sweep a generator over a given frequency range, particularly where you can preset the 'start' and 'stop' frequencies, can be extremely handy. It might be something rarely used, but when you need it, there's *no satisfactory substitute.* Some applications, particularly in the audio field, require sweep facilities often. There was no getting away from it — the sweep facility was necessary.

Triggered and gated signals are used less often, except in certain specific fields — such as loudspeaker evaluation. It was decided that this generator could do without the nicety of triggering and gating facilities.

An important consideration on any generator is frequency readout. There are two fundamental ways one can approach this — the mechanical way or the digital way. The mechanical way has the advantage of being cheap and pretty direct. The Wavetek 166 has a calibrated skirt on the frequency knob. That's fine, except in those (increasingly numerous) applications where you need to know the frequency to, say, 1 Hz in 1 kHz. Out with the digital counter! That's all right, except where you need to use the counter for other things while you're using the generator.

I opted for digital frequency display. This gave me an additional option — the ability to use a 10-turn potentiometer in place of a conventional pot. for the frequency setting control. You don't have to, but the possibility is there.

The basic functions and features settled on turned out to be:

- 1Hz to 1 MHz frequency range
- sine, triangle, square, sawtooth (ramp-up and ramp-down) and pulse outputs
- TTL level positive- and negative-going pulse outputs with variable width
- sweep facility
- output voltage range from millivolts to at least 10 V
- dc offset provision
- digital frequency display.

As the project was to be part of the 'lab-standard' series, I next had to define 'lab-standard' with regard to function generators.

The definition

This proved a difficult task as there are conflicts between *desirable* performance and *reasonably achievable* performance. It's like saying a desirable goal for a jogger would be to jog up Mount Everest and back, but it's one that is hardly reasonable to achieve. Keeping that in mind, I set about putting numbers to the various performance figures required of the generator project.

An obvious first one is sinewave distortion. Wavetek's lower cost, lower performance function generators quote a sinewave distortion figure of 1% to 500 kHz for a generator going to 5 MHz. Other brands quote 2% to 5% distortion figures. If you want to measure the total harmonic distortion of an audio amplifier, then you really need a special low-distortion oscillator. Thus, it seems to me that a sinewave output distortion of 1% to 2% would be tolerable, if not more than adequate.

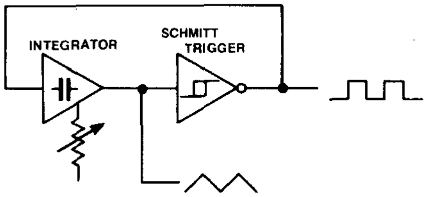


Figure 1. Fundamental arrangement of a function generator oscillator.

Triangle and sawtooth linearity should be at least 95%, preferably close to 99%, right across the frequency range.

Frequency readout is important. When messing around with audio filters, modems and the like, the ability to measure at least 1 Hz in 1 kHz is highly desirable. A simple 3½-digit counter will allow you to read 1 Hz in 2 kHz (for argument's sake . . .), which is quite sufficient in a huge variety of applications. If you want more accuracy than that, then it's time to dig out your six- or eight-digit counter!

The output attenuator, as stated earlier, needs to be able to provide signals down in the millivolt region on one hand, yet the maximum output level desirable was set at 10 Vp-p. Then there's the 10 dB steps. Well, all that's pretty simple. A six-range attenuator will give steps of 10 V, 3 V, 1 V, 300 mV, 100 mV and 30 mV. A pot. simply allows infinite variation over whatever maximum level range is set on the attenuator.

The pulse width range was not so difficult to define. From experience, pulses greater than one second wide are not often encountered or required, so that fixed a reasonable upper limit. Pulses around 100 nanoseconds wide are encountered more often, as well as a whole host in between. A vernier control would permit variation up to a set maximum pulse width. Thus, I made the pulse width ranges 100 ms-1 s, 10 ms-100 ms, 1 ms-10 ms, 100 us-1 ms, 10 us-100 us, 1 us-10 us and 100 ns-1 us.

For the sweep function, being able to sweep over a three-decade range (1000:1) is desirable, but problematical to achieve. I settled for being able to sweep the generator over any one-decade range.

We found the modulation facility of the lab. Wavetek was rarely used. That sort of thing's essential on an RF signal generator (. . . all right, all right — we'll get round to it), but of rare application in a function generator such as this. Hence, no modulator.

I decided that providing gating facilities on the function output was a specialised application. If you need it, then the ETI-124 Tone Burst Gate (Nov, '75) should suit most applications.

The technology

The fundamental circuit of a function generator is shown in Figure 1. This consists of an op-amp integrator followed by a Schmitt trigger with a feedback path between the Schmitt trigger's output and the integrator's input. Such a circuit is arranged such that, at power-on, the Schmitt trigger output goes high and charges the integrator capacitor. The integrator's output rises linearly until the Schmitt trigger's upper threshold is reached, where the output goes low. The integrator's capacitor then discharges linearly until the Schmitt trigger's lower threshold is reached, where the output reverts to the high state once again.

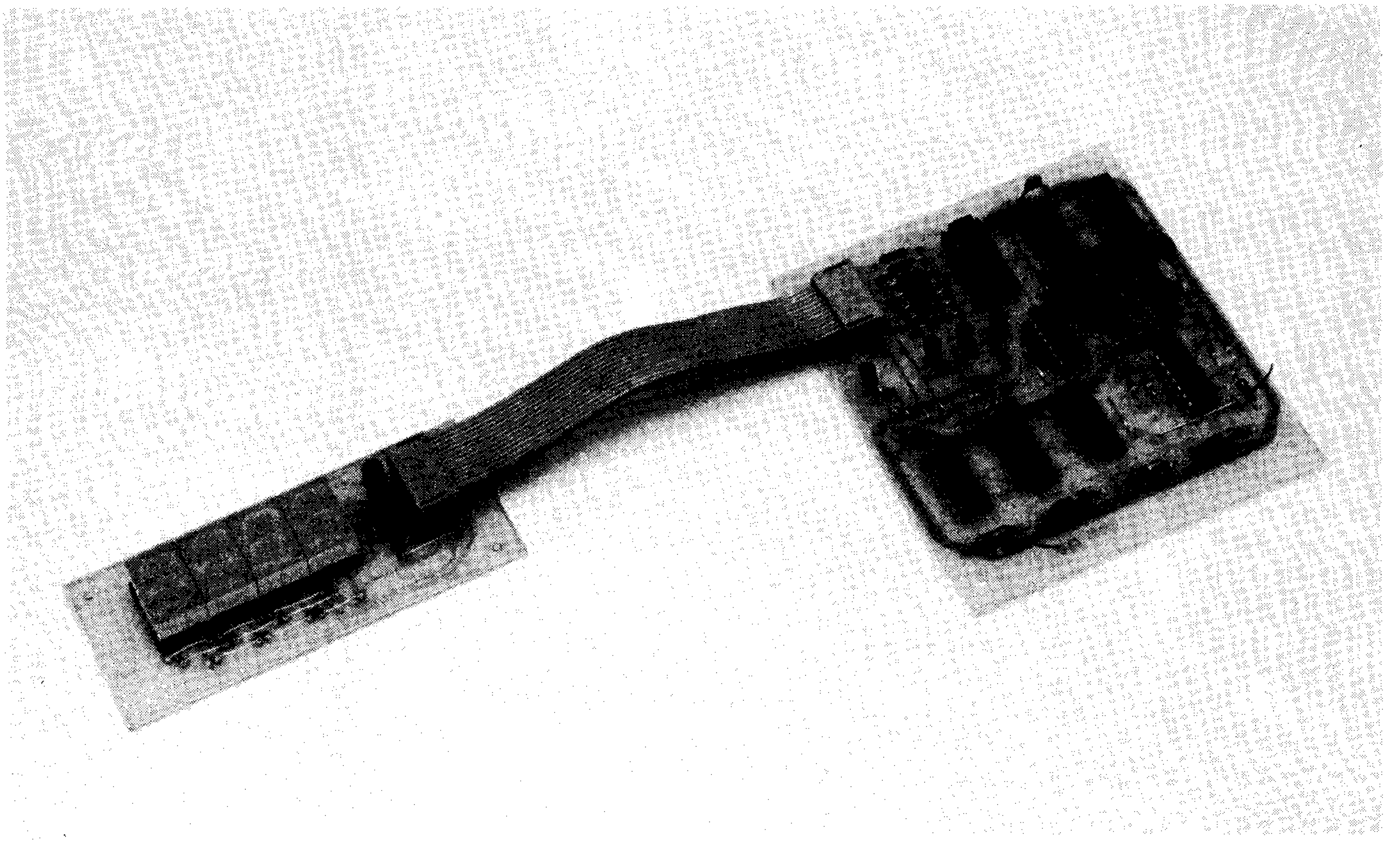
The variable resistor in the diagram is there to indicate that the integrator's charge and discharge rate can be varied (the rates will be the same), thus varying the oscillation frequency as the time taken to reach the Schmitt trigger's upper and lower threshold is varied.

To obtain a sinewave, the triangular wave output is rounded, or 'shaped', with a special circuit. Sawtooth waveforms are generated by having different charge and discharge times for the integrator. A 'ramp-up' waveform is generated by charging the integrator's capacitor slowly and discharging it quickly. A 'ramp-down' waveform is obtained by charging the capacitor quickly and discharging it slowly.

There are a number of special ICs available that provide the fundamental circuit blocks to make a function generator. The XR2206 and the 8038 are probably the most well-known ones. Unfortunately, neither meets most of the performance requirements set down earlier in this article. At best, the XR2206 will only get to 150 kHz and the waveform 'trueness' begins to fall off once it gets past about 20 kHz. It's a fine IC for non-critical applications, such as a low-cost 'knockabout' function generator. The 8038 is better — it will comfortably get to 500 kHz, but, again, waveform trueness is nothing wonderful well below that limit.

To meet the requirements set down earlier, I had to tackle the project in discrete 'blocks'. The block diagram in Figure 2 is the result. That is the overall block diagram of the ETI-166 Function/Pulse Generator.

Constructionally, the ETI-166 has been divided into logical modules — the main generator, the frequency counter and display and the output amplifier. The latter has been dubbed Project 1520 and appears elsewhere in this issue. ●



A laboratory standard function and pulse generator

Part 2.

This article covers the design and construction description of the frequency counter and power supply modules. Like the wideband amplifier (ETI-1520) module, these two can also be used in other applications.

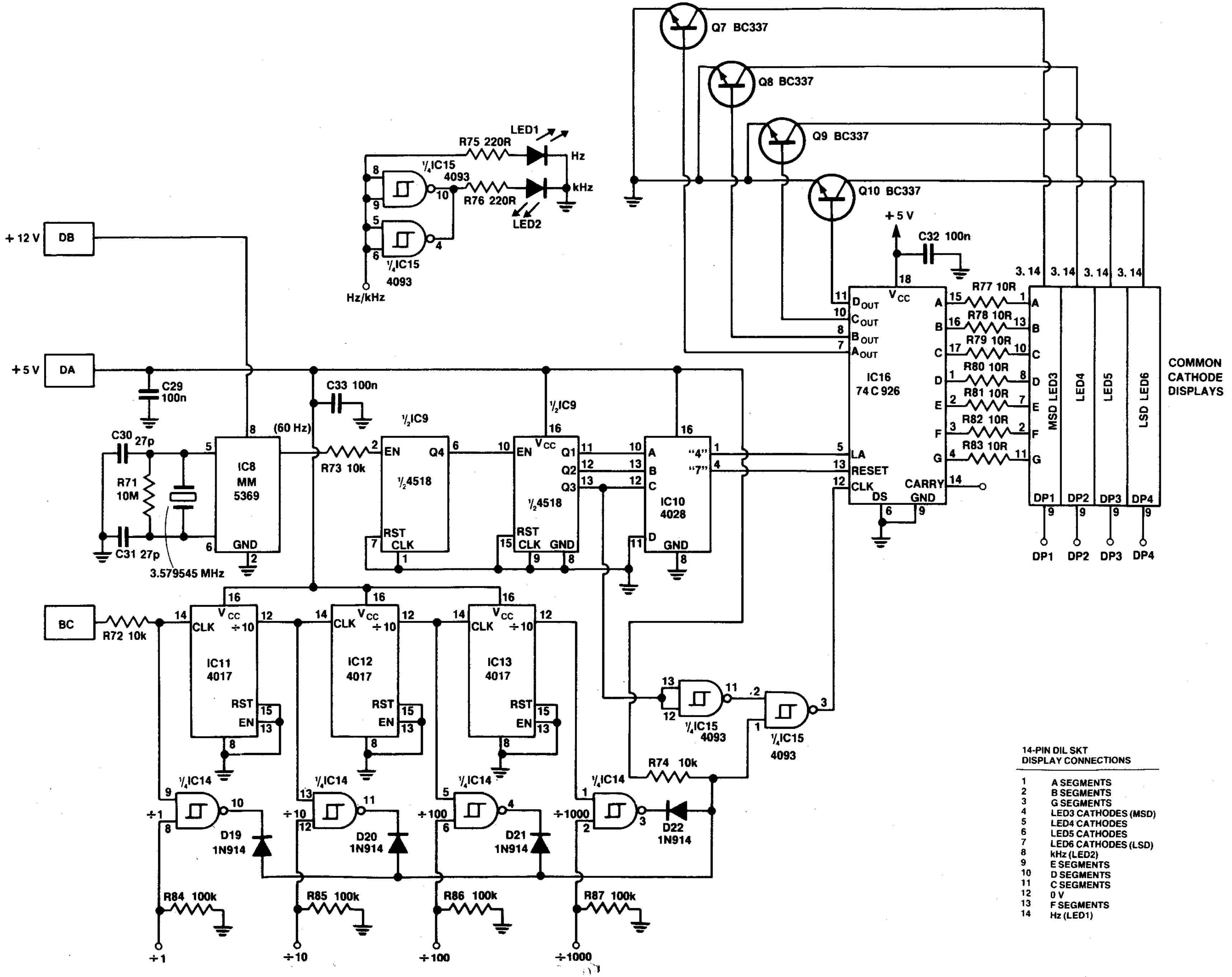
David Tilbrook

THE TWO MODULES to be described here, the frequency counter and power supply sections of the Function/Pulse Generator, can be used in applications aside from this project. For the moment, we'll leave the details to you and get on with the project in hand. Both modules have been designed to do the job required, yet keep costs low. No really 'specialised' components have been employed and constructors should have little difficulty obtaining kits or individual parts.

FREQUENCY COUNTER

This is housed on two boards — one containing the counter electronics, the other containing the 4-digit 7-segment LED display and Hz/kHz indicators. The counter board measures 95 x 105 mm, while the display board measures 40 x 100 mm. Spacious component layout is employed on each, easing construction.

A total of nine ICs are employed, but they're all off-the-shelf types and the reference is derived from a low-cost common crystal. The displays finally selected, after a great deal of shopping around, are high-efficiency Stanley types, the NK#-163 series. The # letter signifies the colour — A for amber, R for red, etc. We used the amber displays because they are very 'visible', easy on the eyes and the red displays were unobtainable! (Grr ... Ed.). Litronix LT-547 displays are physically identical, but do not feature the high efficiency LED segments. ▶



14-PIN DIL SKT
DISPLAY CONNECTIONS

1	A SEGMENTS
2	B SEGMENTS
3	G SEGMENTS
4	LED3 CATHODES (MSD)
5	LED4 CATHODES
6	LED5 CATHODES
7	LED6 CATHODES (LSD)
8	kHz (LED2)
9	E SEGMENTS
10	D SEGMENTS
11	C SEGMENTS
12	0 V
13	F SEGMENTS
14	Hz (LED1)

Design

The heart of this counter is a 74C926 counter/display driver IC. A 1 Hz gate period is derived from a 3.579545 MHz crystal using an MM5369A oscillator/17-stage divider IC, which provides a 60 Hz output, followed by a 4518 dual 4-stage counter, half of which divides the 60 Hz to 6 Hz, the other half dividing this to 1 Hz. A 4028 BCD-to-decimal decoder provides the appropriate gating signals to the 74C926.

The incoming frequency to be displayed is gated through to the 74C926 clock input, only for the period for which the counter/display is enabled so that a steady display results.

The output of one of a series of 4017 dividers, driven by the input signal, can be selected to provide divisions of 10,100 and 1000. The counter can display input frequencies to 2 MHz, limited by the speed of the CMOS circuitry. Decimal point switching and divider selection is arranged by an external switch — the range switch of the main oscillator. The Hz/kHz indicator switching is also provided by the generator's range switch.

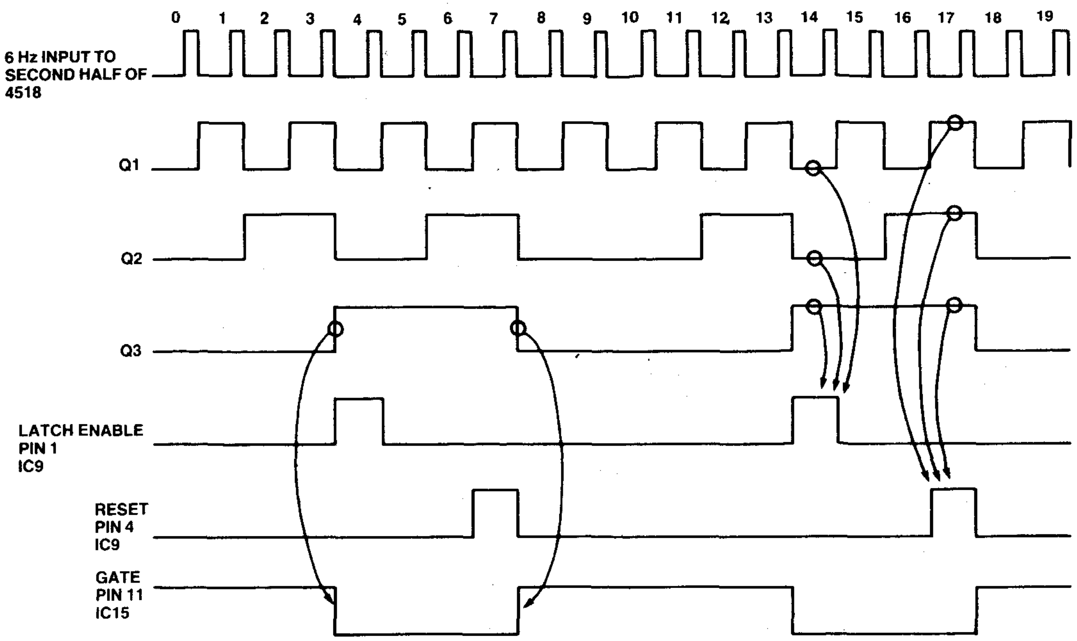
Note that the 74C926 multiplexes the displays. This chip's 'carry' output is brought out to a pad on the counter board so that this module can be used stand-alone as a $4^1/_2$-digit counter.

Construction

The first thing you should do is check your pc boards, no matter whether you've bought them or made them yourself. Check the tracks for minute 'bridges', particularly where they run between IC pins, and also that there are no minute cracks — many of the tracks are quite fine. See that all the holes are correctly drilled. Fix any problems before proceeding.

Tackle the counter board (ETI-166b) first. The component overlay shows the overall arrangement. Install all the resistors and capacitors first. Mount the capacitors with as short leads as possible. Install the nine links next. Note that one solders to a lead of resistor R74 (near the location of the crystal).

▶



HOW IT WORKS — ETI 166b

The frequency reference is derived from a 3.579545 MHz crystal and a MM5369 oscillator/divider. This combination produces a crystal-locked 60 Hz output which is further divided to provide a 1 Hz gating signal accurate enough to ensure that all displayed digits are meaningful.

A ceramic resonator may have also have sufficed since only four digits are displayed.

The technique of using a mains derived 50 Hz signal instead of a crystal was not used since the short term accuracy of the mains is not sufficient to ensure that all digits displayed are valid.

The output of the MM5369 is fed to one half of a 4518 dual BCD up-counter which is used to divide the input 60 Hz signal by ten. This provides a 6 Hz signal which is used as the input to the second half of the 4518.

This stage, in combination with the 4028 BCD decimal decoder, generates latch-enable, gating and reset signals which are required by the 74C926 seven-segment display driver.

The timing diagram shows the relationship between the control signals and the 6 Hz input to the second stage of the 4518.

Since the 6 Hz signal is derived from the Q4 output of the first stage of IC9, it has a 2:8 mark/space ratio. This input frequency is counted by the second stage of IC9 which provides a BCD output corresponding to the count at any given time.

Notice that the Q3 output is low for exactly six cycles of the input clock i.e: low for one second. This signal is inverted by one gate of IC15 (4093) and used as an accurate 1 Hz gating signal.

This signal is NANDed with the input signal, to be measured in another gate of IC15 so that the input frequency (signal at pin 1, IC15) is counted by the 74C926 for a period of one second. At the end of this time gating stops.

The output of the 4518 is decoded by the 4028 and the '4' output is selected as the latch-enable line. As can be seen from the timing diagram, this line goes high immediately counting ceases and the measured frequency is displayed.

The displayed frequency will not change again until a completely new measurement is carried out one second later.

A short time after the latch-enable signal, the '7' output of the 4028 goes high and this is used to reset the counter within the 74C926, in preparation for the new measurement.

The 74C926 automatically counts the input frequency, converts it to seven-segment code and drives the seven-segment displays. The displays are multiplexed by the 74C926 so that only one is on at any given time to decrease current consumption and power dissipation.

We tried a variety of seven-segment displays and finally chose the Stanley NKA163-B since it is considerably brighter than any other display tried. The pinout on these displays is the same as that on a variety of displays so availability should not be a problem.

The remaining section of the frequency meter is formed by IC11, IC12, IC13 and IC14. This circuitry divides the input by 1, 10, 100 or 1000 to provide range switching. IC11, IC12 and IC13 are decade counters, each providing a ÷10 function. The outputs of the counters are fed to the inputs of successive counters and to the inputs of the NAND gates (IC14).

The desired input prescaling is obtained by taking the other input of the gates to +5 V. The resistors R84, 85, 86 and 87 are used to hold these gates at ground potential unless driven.

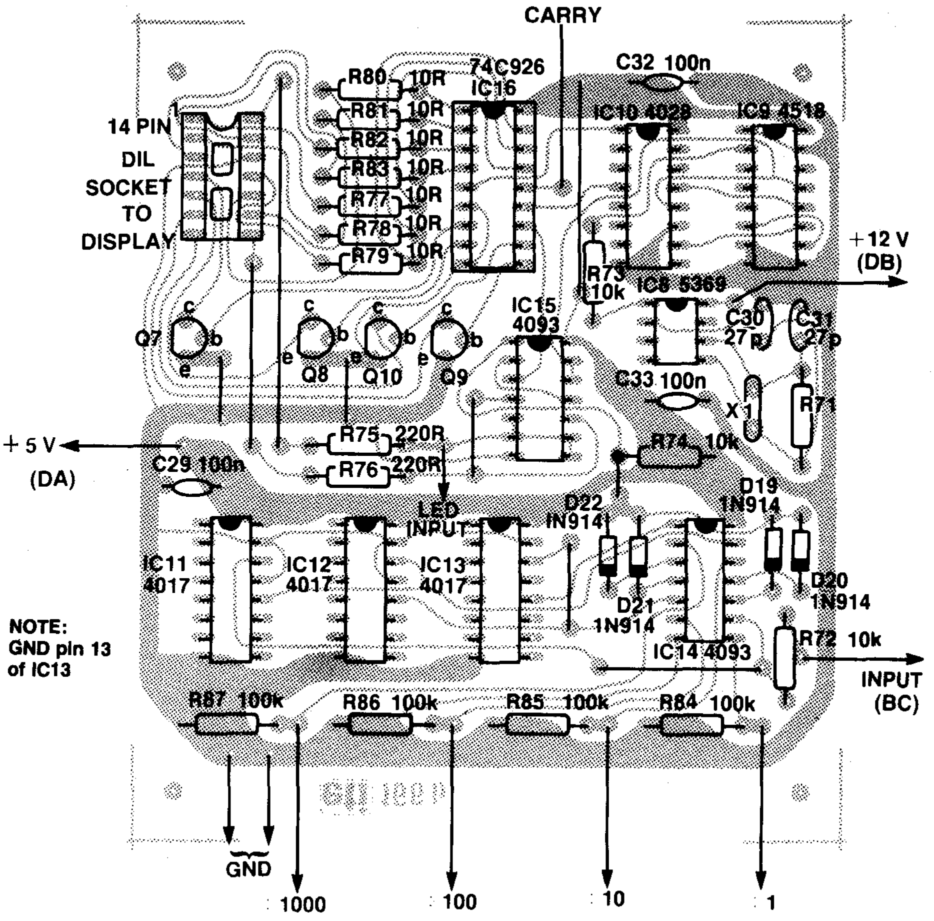
The maximum frequency that can be measured is around 2 MHz and this is determined by the first decade counter IC11. If a high frequency is required simply incorporate a TTL ÷10 stage before the input with a 1k pull-up resistor on its output to the +5 V rail. This would enable the meter to measure to around 20 MHz.

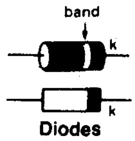
PARTS LIST — ETI-166b,c FREQUENCY COUNTER

Resistors	All ¼W, 5% unless noted
R71	10M
R72, 73, 74	10k
R75, R76	220R
R77-83	10R
R84-87	100k
Capacitors	
C29, C33	100n
C30, 31, 32	27p
Semiconductors	
D19-22	1N914, 1N4148
IC8	MM5369AA (60 Hz model)
IC9	4518
IC10	4028
IC11, 12, 13	4017
IC14, IC15	4093
IC16	74C926
LED1, LED2	TIL220R
LED3-LED6	Stanley NKA-163-B, Litronix LT-547R or similar common cathode 7-segment display with DP.
Q7-10	BC337-BC338
Miscellaneous	
X1	3.579545 MHz crystal, HC18/U can.

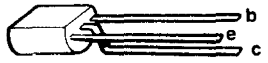
ETI-166b and c pc boards; 2 x 14-pin IC sockets (others if required); 2 x 14-pin IDC plugs; length of 14-way ribbon cable; tinned copper wire; pc stakes, etc.

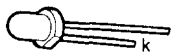
Price Estimate $42-$48



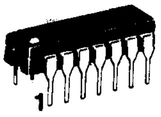


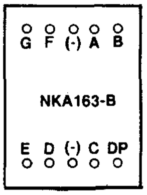
Diodes





LED, TIL220R





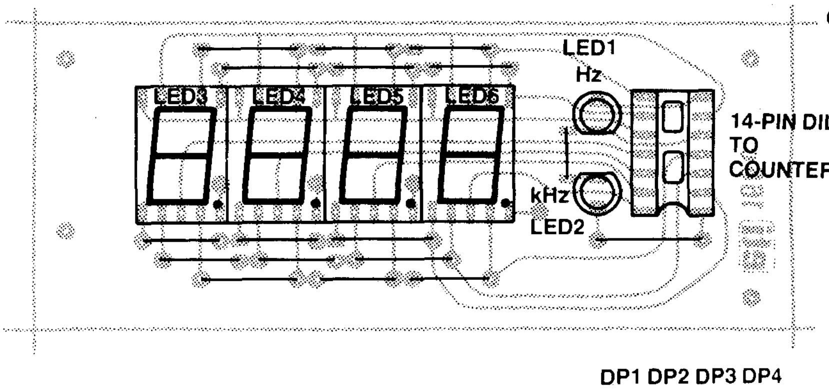
Solder the four diodes and four transistors in place next. Note their orientation before installation; each set faces the same way.

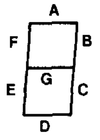
The ICS can be installed next. The 74C926 *(IC16)* requires a socket. This is to provide some heat dissipation for it as there is insufficient copper in the tracks around it on the board to provide enough heatsinking. There are no objections to using IC sockets for the rest of the ICs if you so wish. Note that all the ICs face the same way. Install a 14-pin IC socket for the display interconnection.

The crystal should be soldered in place last of all. Mount it right down on the board — it's not good to have it flapping around in the breeze — and take care not to apply too much heat or hold the iron on the leads for longer than about 10 seconds.

The display board can be assembled next. Install the 17 links first. I used a 40-pin IC socket for the displays and this should be installed next, followed by the 14-pin socket for the interconnection from the counter board. Solder the two LEDs in place next, mounting them so that their bases are 9-10 mm above the board. Then plug the four 7-segment displays into the 40-pin socket.

Strip a short length of ribbon cable to leave 14 wires and cut it to a length of at least 125 mm. Install 14-pin insulation displacement connector (IDC) plugs on each end and the counter is ready!





STANLEY NKA163-B COMMON CATHODE

POWER SUPPLY

The power supply board is quite straightforward. It has been designed to use a transformer delivering 15-0-15 Vac at around 1 A and provides three regulated rails — +5 V, +12 V and −12 V.

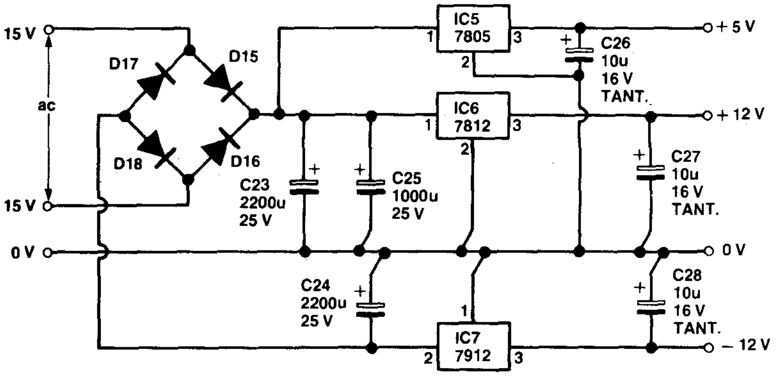
A 6672 transformer is ideal to drive it. This has a multi-tapped secondary delivering an overall 30 V, tapped at 15, 17.5, 20, 24 and 27.5 volts. The 0, 15 and 30 volt taps are used, the 15 V tap being the centre-tap ('C.T.'). It is rated at 1 A.

Apart from its application in this project, this power supply could be used with many microprocessor and digital or digital/analogue circuits. ▶

Construction

Simple! However, check the board first — mainly to see that all the holes are correctly drilled. Solder the four diodes and three tantalum capacitors in place first. See that they are correctly orientated — check with the overlay diagram.

All external connections to and from the board are made via pc stakes and these should be installed next. Follow by installing the three 3-terminal regulators. Last of all, solder the three electrolytic capacitors in place, making sure you get them the right way round. Mount them right down on the board, it's not good to have them waving around on their leads. ●



PARTS LIST — ETI-166d

POWER SUPPLY

Capacitors

C1	1000u/25 V single-ended electro.
C2, C3	2200u/25 V single-ended electro.
C4, 5, 6	10u/16 V tantalum

Semiconductors

D1-4	1N4001, 1N4002, EM401, etc
IC1	7805
IC2	7812
IC3	7912

Miscellaneous

ETI-166d pc board; small heatsinks for TO-220 devices (e.g.: Thermalloy 6073B or similar; pc stakes, etc.)

Price Estimate $14-$16

HOW IT WORKS — ETI-166d

POWER SUPPLY

The power supply comprises fullwave positive and negative capacitor-input rectifiers followed by three, three-terminal regulators developing a +5 V rail, a +12 V rail and a -12 V rail.

The positive rectifier consists of diodes D2 and D3 plus capacitors C1 and C2. With an input from a transformer secondary delivering no greater than 15-0-15 V at 1 A, the voltage developed across C1-C2 is about 21-22 V under load.

IC1 regulates this to +5 V and a load no greater than 250 mA can be drawn without IC1 being mounted on a larger heatsink. Capacitor C4 lowers the regulator's output impedance and maintains its stability.

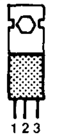
IC2 regulates the positive rectifier output to +12 V and a load of up to 500 mA can be drawn without IC2 being mounted on a larger heatsink. Capacitor C5 fulfils the same role as C4 does for IC1.

The negative rail rectifier consists of diodes D1 and D4 plus capacitor C3. This also develops around 21-22 V across C3 (negative with respect to the 0 V rail) with 15-0-15 V ac applied to the rectifiers' input.

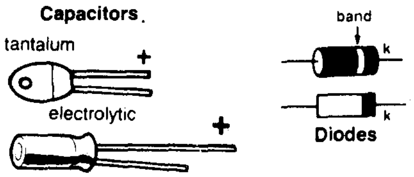
IC3 regulates the negative rail to -12 V and its load can be no greater than 500 mA without the IC being mounted on a larger heatsink. Capacitor C6 lowers the output impedance of IC3 and maintains stability.

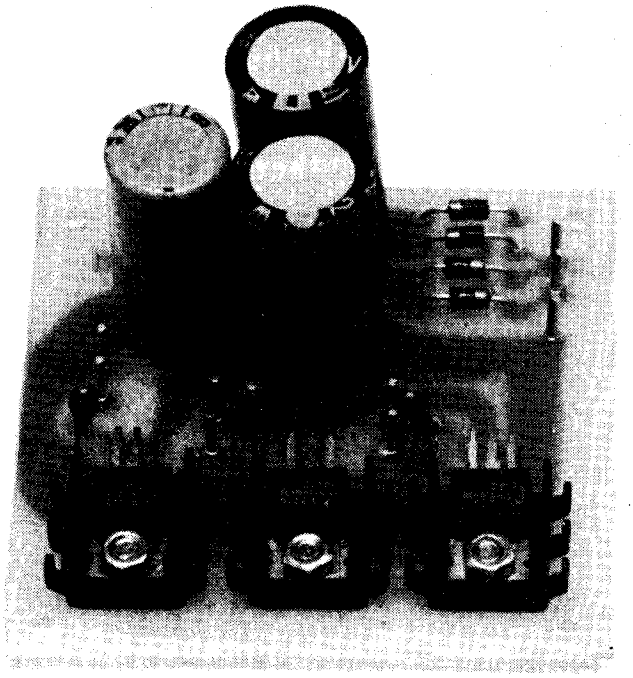
The sum of the load currents on the three supply rails should not exceed the current rating of the transformer.

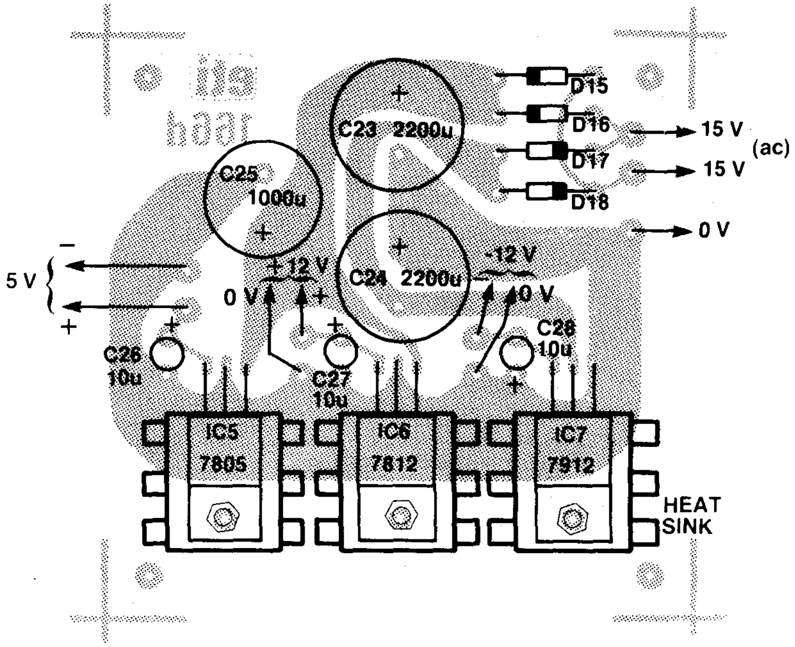
VOLTAGE REGULATOR PIN OUT

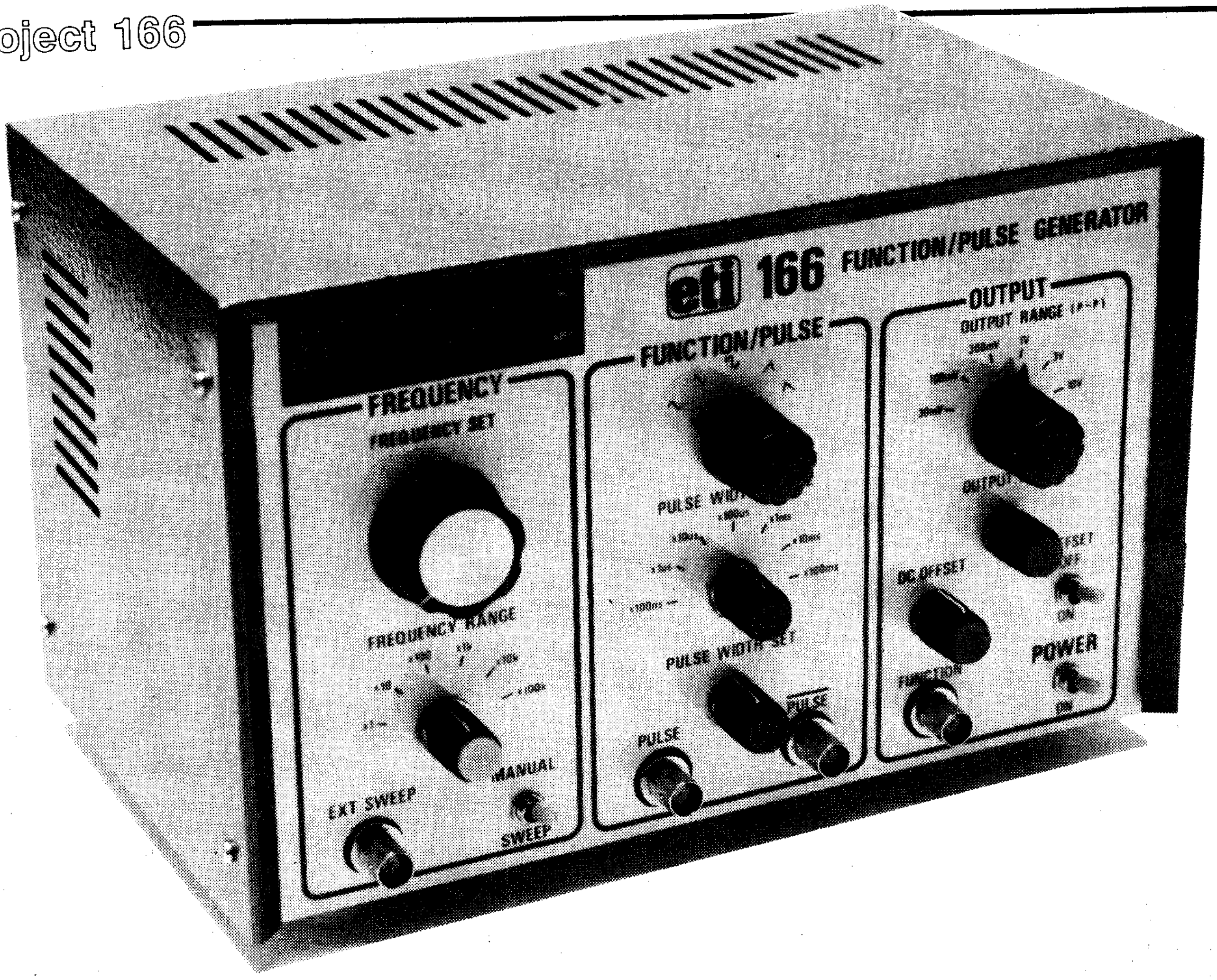


	1	2	3
78XX	IN	0 V	OUT
79XX	0 V	IN	OUT









A laboratory standard function and pulse generator

Part 3

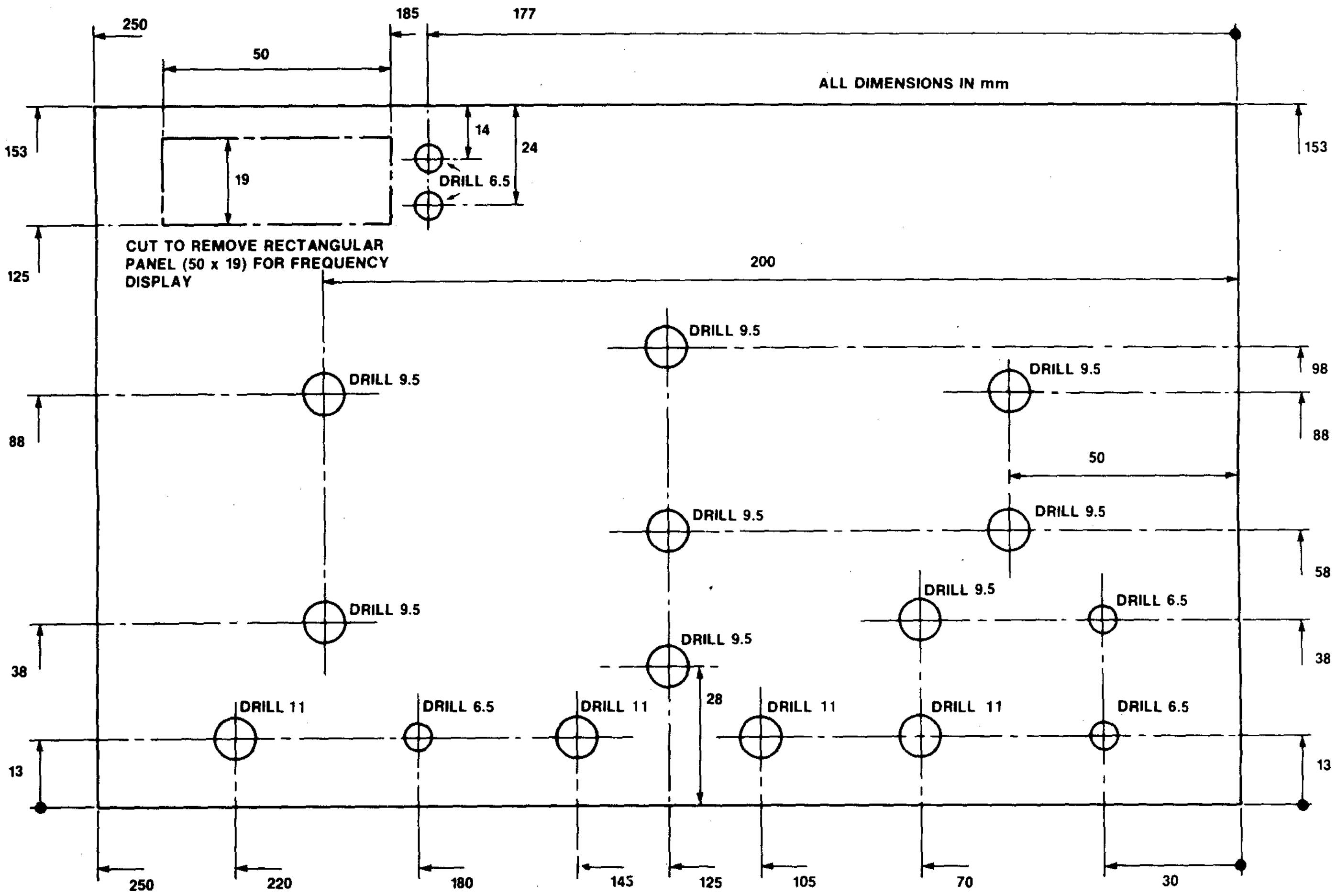
David Tilbrook

This instalment covers the preparation of the chassis and installation of the power supply and output amplifier modules. Do the chassis preparation carefully and you'll be assured of a 'professional' result, with no hassles during assembly. The front panel is particularly critical in this regard, the rear panel and chassis bottom, less so. A fully-dimensioned drawing for all the front panel holes has been prepared and is reproduced elsewhere in this article.

The case I have used is made by the Victorian firm, K&W. It is case No. C1066, the same as used in the ETI-163 Lab-standard Power Supply. In fact, I have designed that power supply and this generator to have a compatible appearance. The chassis of this case is of aluminium, while the lid is steel, having a number of ventilation slots and painted hammertone blue.

The place to start is the rear panel of the chassis. As layout here is generally non-critical, no dimensional drawing has been done. The power supply and the mains transformer are mounted on the rear panel and the mains cable enters at the lower right, when viewed from the front. A drawing of the general layout and wiring diagram of the power supply module and mains shows the details. Mark out the panel with a soft lead pencil, using the components as templates, where applicable. The power supply pc board artwork can be used as a template to mark the position of this module's mounting holes.

When you've marked all the hole centres, centre punch them before attempting to drill the panel. Drill a pilot hole first where large diameter holes have to be drilled (e.g: for the fuse and cable clamp). When the holes have been drilled, check that everything will fit without fouling anything or being cramped. Remove all burrs from the hole rims. Don't assemble anything yet.



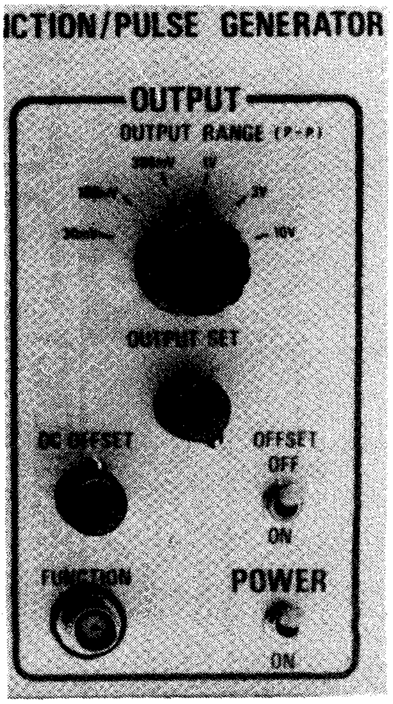
Now mark out the bottom of the case to take the mounting holes for the output amplifier module and the main generator pc board. The main artwork for the ETI-1520 module (reproduced in the article on the '1520) can be used to mark its mounting hole positions. The template drawing for the main generator pc board, reproduced here, can be used to mark out its mounting hole positions. Again, use a soft pencil to mark the hole positions and centre punch them before drilling. Check it after drilling and de-burr the holes.

Now for the front panel. I have to stress that this should be done with the *utmost care*. Follow the accompanying drawing carefully and you should have no difficulty. There is an option, though, that I should point out, with regard to the mounting of the 4-digit LED frequency display. This board, ETI-166c, is mounted with four long screws. The panel could be drilled and countersunk screws employed, but I found that, owing to the thinness of the chassis material, this was not going to be very satisfactory as the screw heads would not sit flush with the panel and thus would show beneath the Scotchcal front panel. Instead, I mounted the screws to the board so that the displays were held a millimetre or so back from the panel cutout and actually *glued* the screw heads to the front panel after carefully siting the display board. The choice I leave to you.

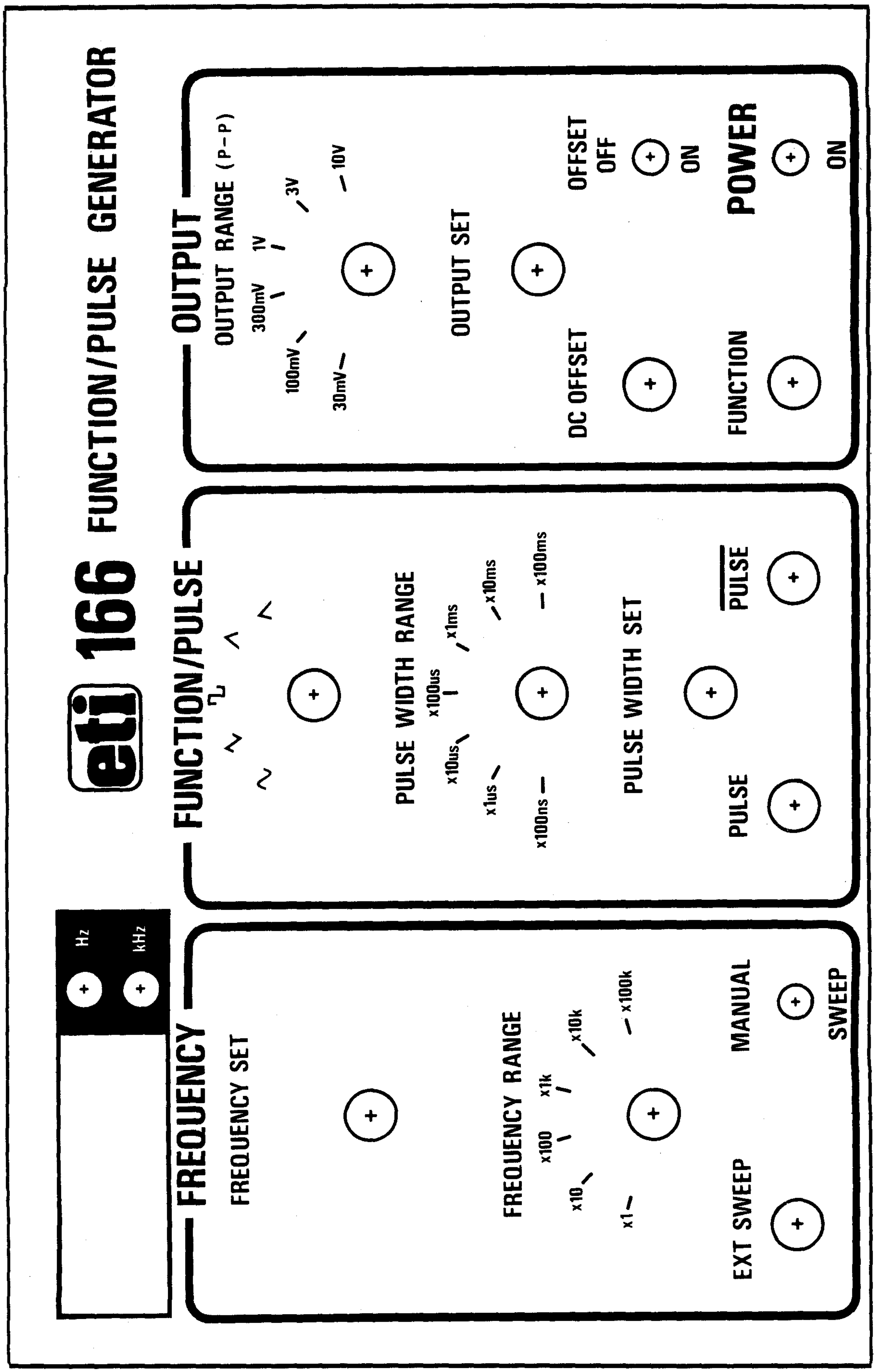
Mark out all the holes very carefully, measuring only from the bottom edge and the bottom right-hand corner, to ensure consistent accuracy. Centre punch all the holes before drilling. Drill a pilot hole first for all the holes, then the correct size drill. De-burr all the holes when you're finished. The LED display slot can be cut out in a number of ways. One way is to drill a series of holes around the inside edge of the hole, a millimetre or so from the marked edges. Break out the centre piece when you've completed the series and then file the edges smooth and straight. Alternatively, drill one large hole for a 'hole nibbler' and cut around the edge with that tool. Some filing will be necessary in this case too.

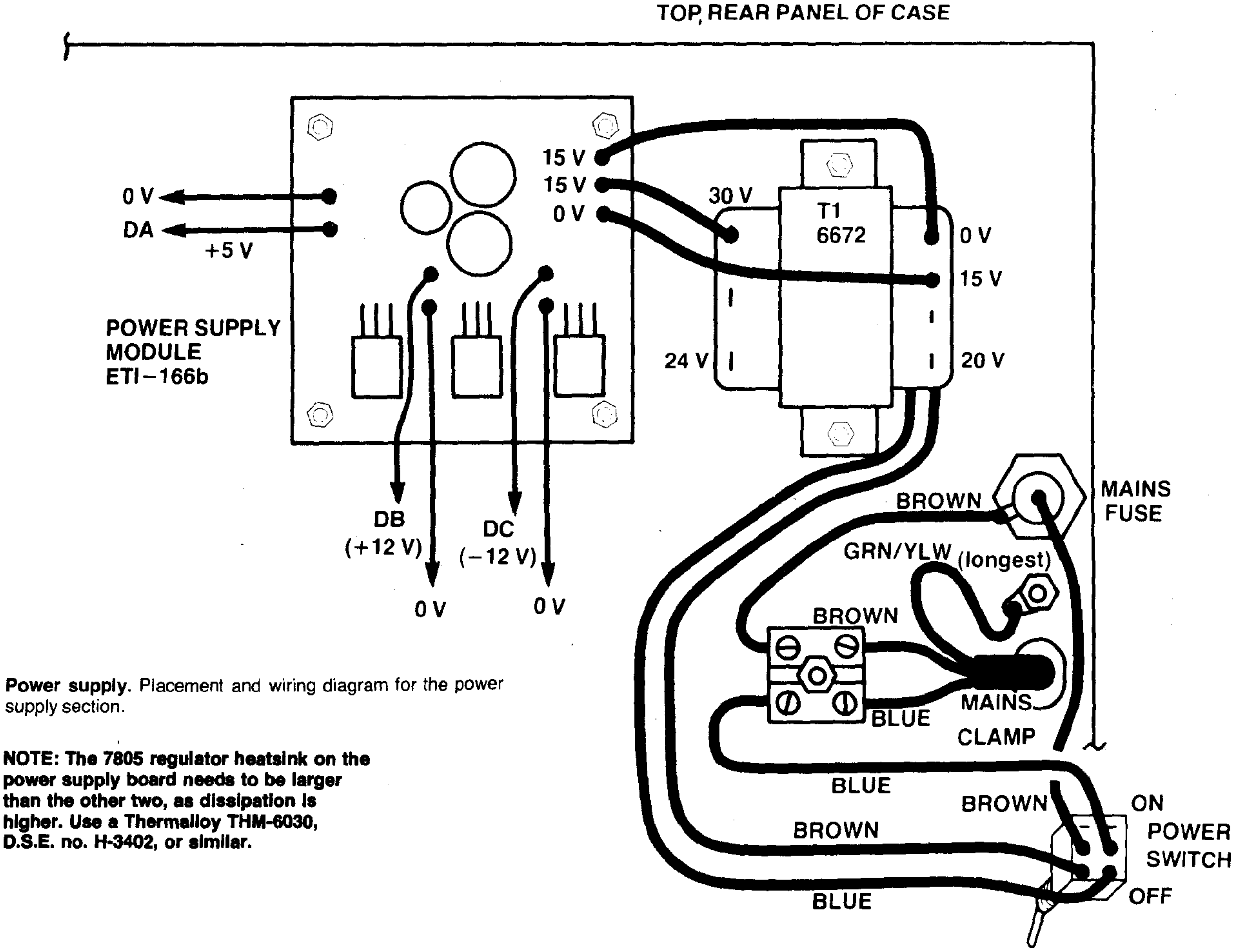
When you're satisfied the panel's finished, you can install the Scotchcal label. I used a plastic one - blue on a white background to match my ETI-163 Lab Supply - but an aluminium one can be used too. If you're using a plastic Scotchcal, paint the panel white first, as the Scotchcal is translucent. Let the paint dry thoroughly before proceeding.

Whether you've made your own or purchased one, the Scotchcal panel should be installed carefully. Start by cutting it carefully to size, then remove a 10 mm strip off the backing from the left-hand edge. Carefully line up the edge of the Scotchcal and the edge of the panel, ensuring that it will lay ▶



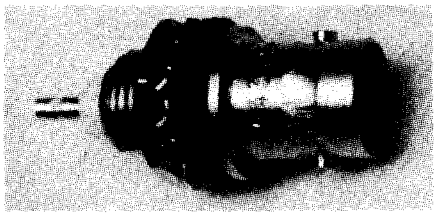
This bit. The assembly of this section and the power supply is covered in this instalment.


eti 166 FUNCTION/PULSE GENERATOR
FREQUENCY
FREQUENCY SET
Hz
kHz
FREQUENCY RANGE
x1
x10
x100
x1k
x10k
x100k
EXT SWEEP
MANUAL
SWEEP
FUNCTION/PULSE
PULSE WIDTH RANGE
x100ns
x1us
x10us
x100us
x1ms
x10ms
x100ms
PULSE WIDTH SET
PULSE
PULSE
OUTPUT
OUTPUT RANGE (P-P)
30mV
100mV
300mV
1V
3V
10V
OUTPUT SET
DC OFFSET
OFFSET
OFF
ON
FUNCTION
POWER
ON



Power supply. Placement and wiring diagram for the power supply section.

NOTE: The 7805 regulator heatsink on the power supply board needs to be larger than the other two, as dissipation is higher. Use a Thermalloy THM-6030, D.S.E. no. H-3402, or similar.



The BNC socket is insulated from the panel by a rubber grommet.

straight, and rub down firmly along the edge. Then, carefully peeling off the backing and rolling it under, rub the Scotchcal down, moving across the panel. This way, you should get no, or very few, bubbles under it. Any you may get can be rubbed away towards one edge as they occur.

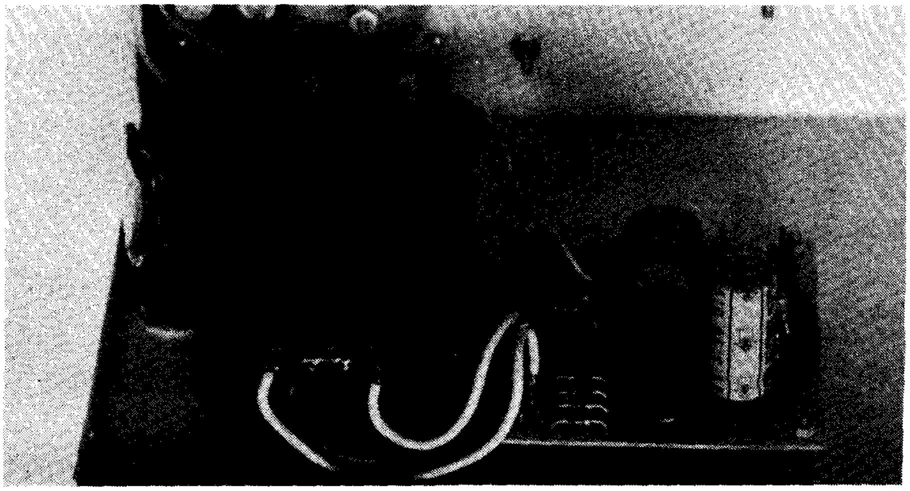
Using a sharp knife point or modeller's scalpel, cut the Scotchcal away from all the holes, being careful not to make any slips or you'll spoil your panel. Tsk, tsk.

Now you can mount the controls in the OUTPUT section of the front panel. There are two toggle switches, two pots and a rotary switch. Here's what you'll need:

1 x BNC socket, panel-mount, with earth lug.
1 x two-pole, 6-position rotary switch.
1 x 1k/A (lin.) pot.
1 x 10k/A (lin.) pot.
1 x SPDT miniature toggle switch.
1 x DPDT 240 Vac/1.5 A min. toggle switch.

Start with the BNC socket. This has to be insulated from the front panel. What I did was to take a 6 mm i.d. rubber grommet and force (roll) it onto the socket's thread after removing the nut, washer and earth lug. This then slips neatly in the 11 mm mounting hole marked FUNCTION. Secure it by putting the washer on first, then the earth lug, followed by the nut. Check that it isn't shorted to the chassis. Then mount the power switch (DPDT), followed by the two pots and the rotary switch. Take care not to scratch the Scotchcal.

Now tackle the rear panel. Mount the terminal block and earth lug, then the mains cable. Strip the end of the mains cable so that the active (brown) and neutral (blue) leads are about 40 mm long and the earth lead (green with yellow stripe) is about 60-70 mm long. Terminate the leads as per the wiring



Rear panel assembly. View of the rear panel showing placement of the various pieces of the power supply. I used a different transformer from the 6672 specified as I had one on hand but no 6672. Note the rear edge of the ETI-1520 output amplifier module.

diagram. The neutral lead (blue) from the terminal block to the mains switch should be attached to the terminal block next. This should be about 300 mm long, but don't wire it to the switch yet. The active lead (brown) between the terminal block and the mains fuse is about 200 mm long and should be attached to the terminal block next, but not to the fuse. The lead between the fuse and the mains switch can be attached to the fuse now, first slipping a length of heatshrink tubing over the two leads to the fuseholder. After the leads are soldered to the fuseholder, apply a blast of hot air to the sleeve so that the fuseholder terminals are not exposed. Now solder two 400 mm long leads to the mains terminals of the power transformer, one brown, one blue. Sleeve the terminals. Then mount the power transformer.

Note that all mains wiring should be done with mains-rated hookup wire.

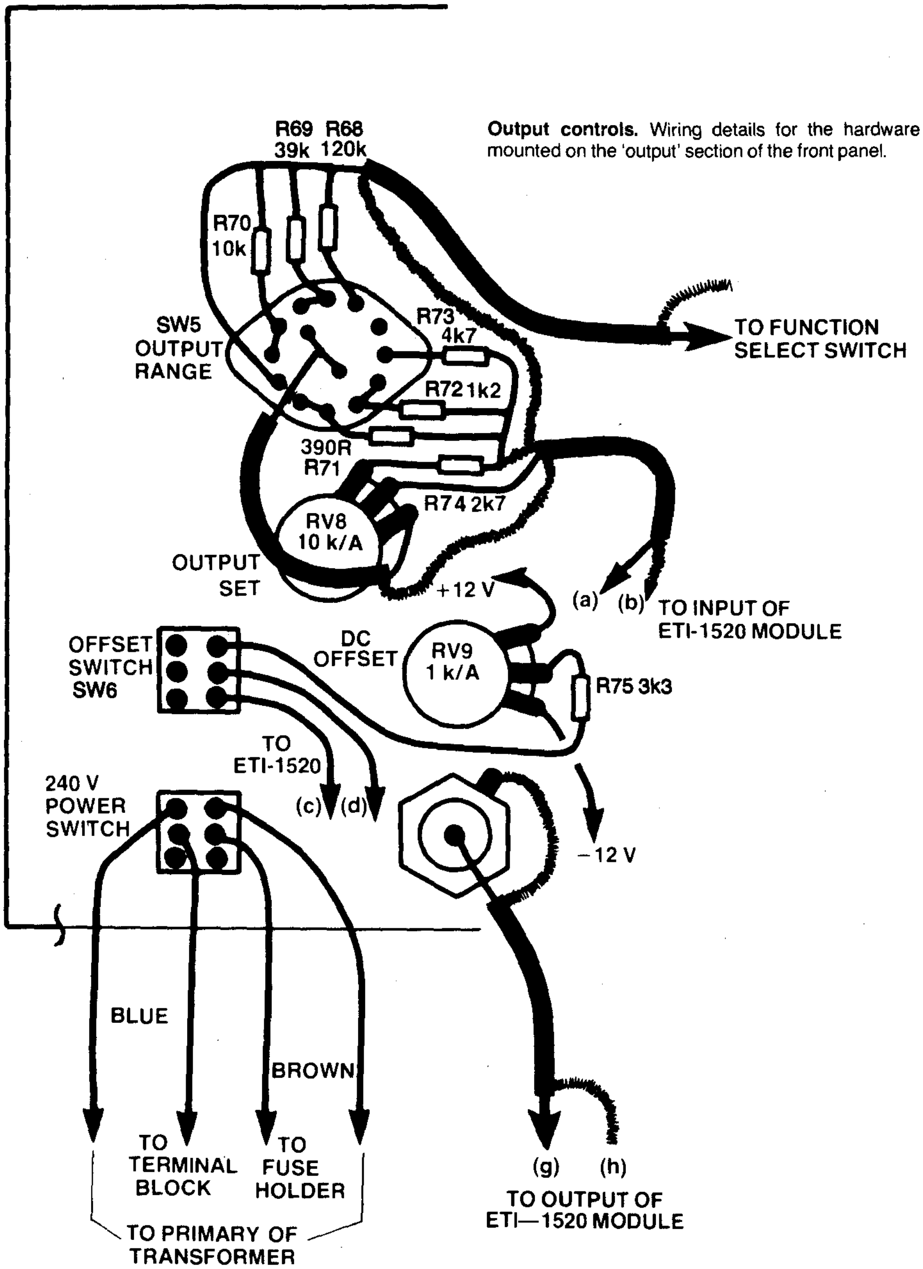
The ETI-166d power supply module can be mounted next and wired to the transformer. Use heavy duty hookup cable, at least 24 x 0.2 mm.

Now the ETI-1520 output amplifier module can be mounted in place. Note that the pc stakes or short lengths of tinned copper wire are used on the board for attaching the external wiring.

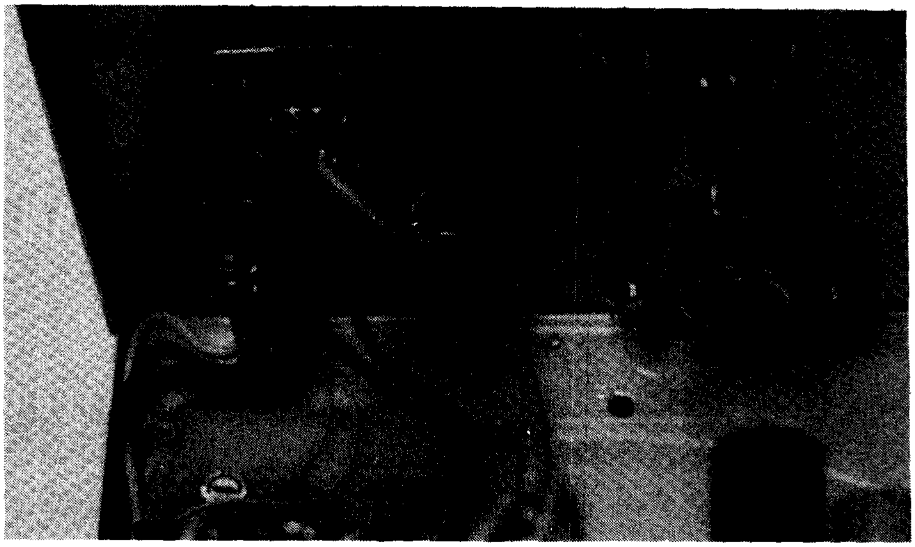
The power switch can now be wired up. Note that the neutral side wiring is nearest the edge of the chassis, for safety's sake. Don't forget to sleeve, or otherwise cover, all exposed mains connections.

With that completed, tackle the rest of the output stage wiring. The details are clear from the accompanying wiring diagram. The components you need are shown there. Don't worry about the numbering at the moment, all that will come together with the next instalment. The resistors are all ¼ W, 5% types. Note the use of shielded cable on the ETI-1520 input and output lines.

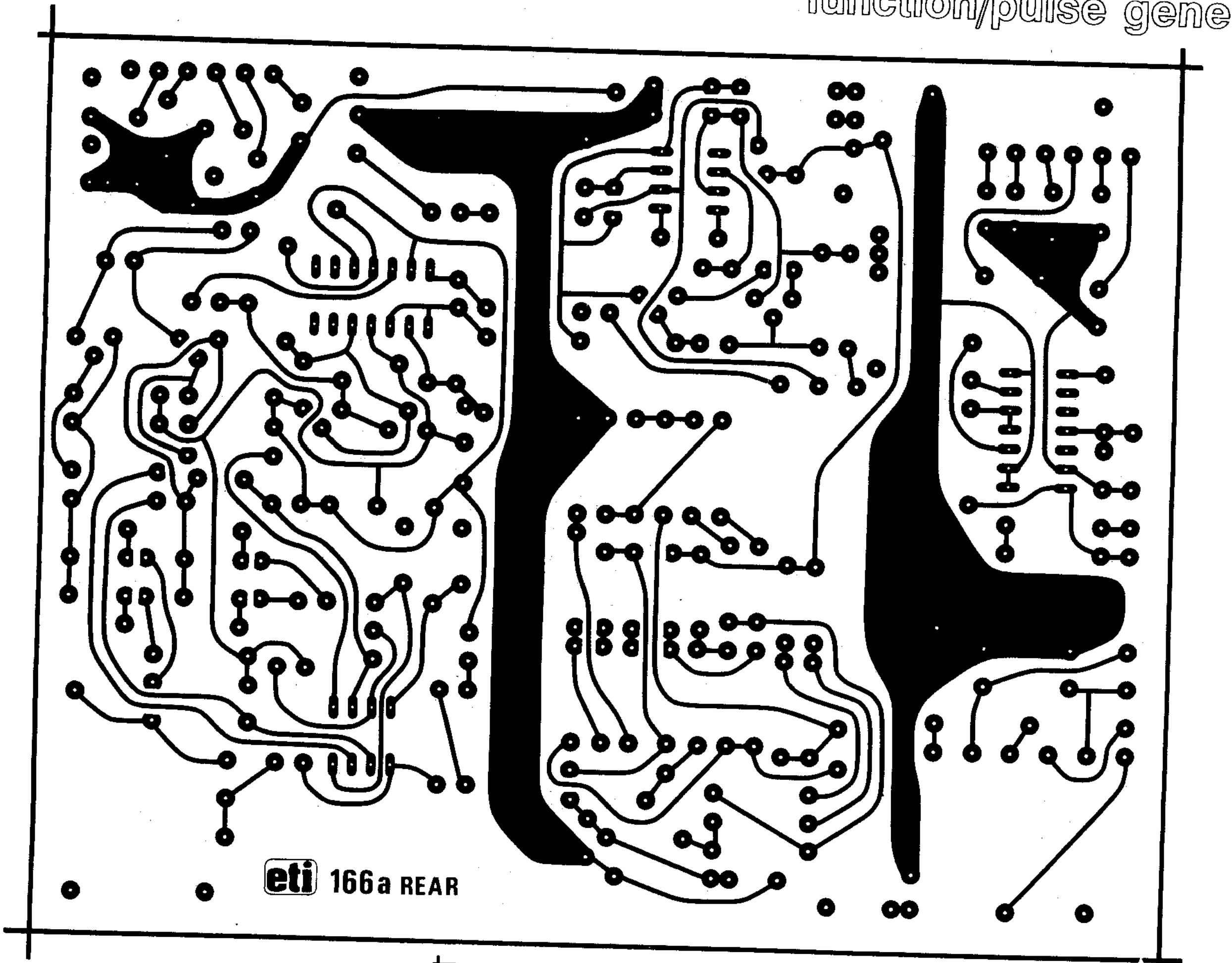
That's as far as you can go for the moment — but that lot should keep you occupied for some time. ●

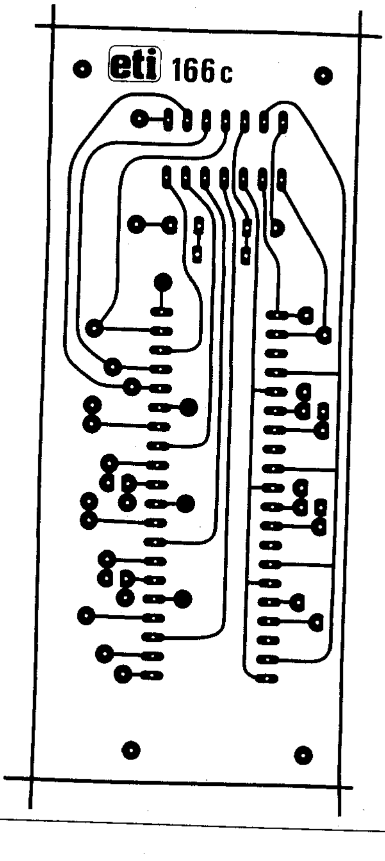


Output controls. Wiring details for the hardware mounted on the 'output' section of the front panel.



Behind the front. General view of the hardware mounted behind the front panel.


eti 166a REAR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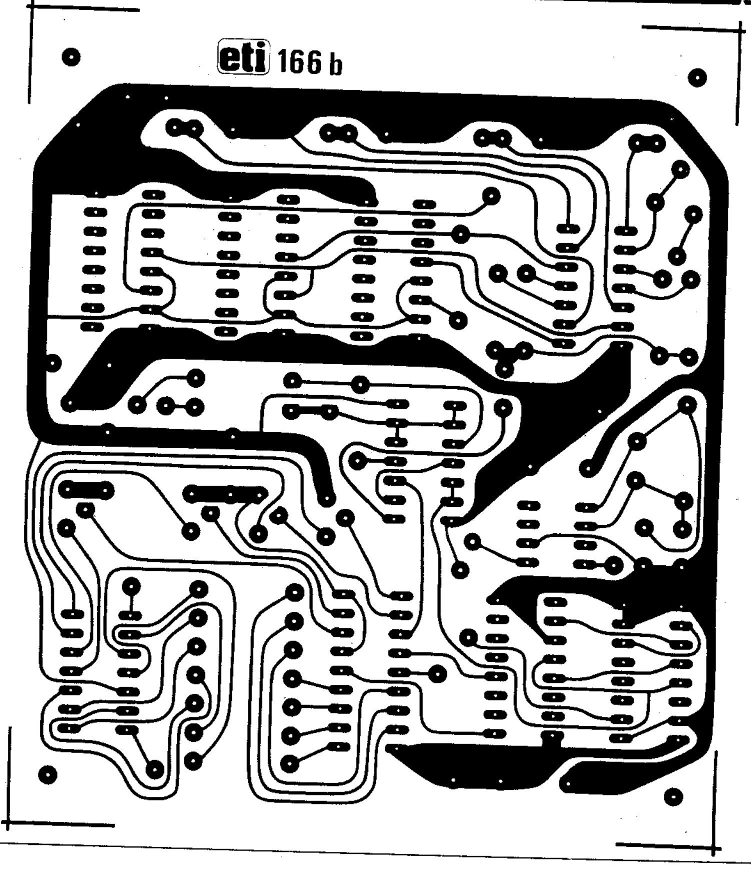

eti 166b

A laboratory standard function and pulse generator

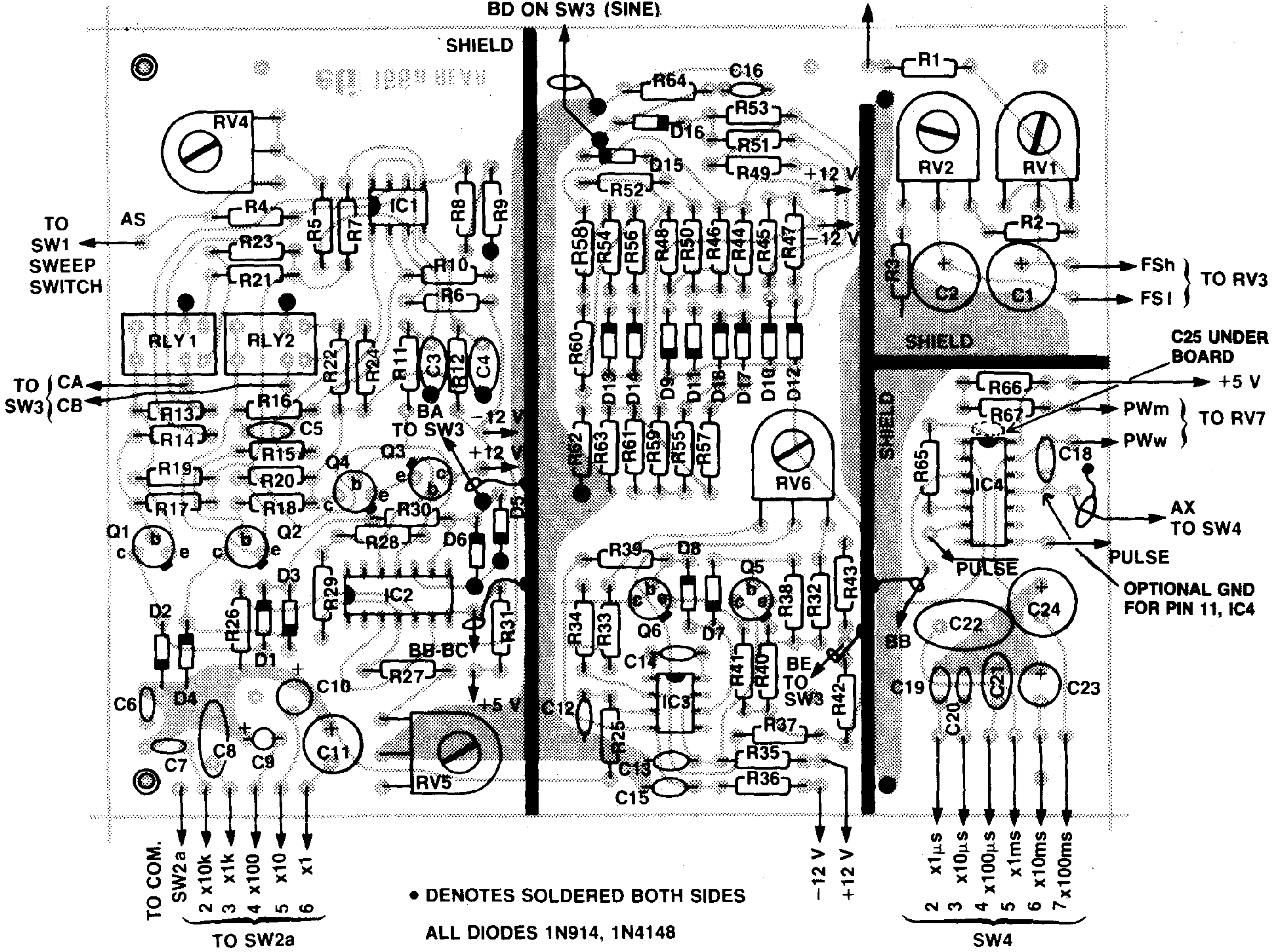
Part 4

David Tilbrook

THIS INSTALMENT covers construction of the main generator board plus final assembly and setting up. I had to employ RF construction techniques on the main generator board as high speed signals are generated, pc tracks start to behave like transmission lines and 'reflections' cause ringing at certain portions of the waveform, spoiling the purity of the generated signal. Also, because high speed switching transients are generated by portions of the circuit, I found that shielding between sections of the generator circuitry was necessary to prevent these transients being coupled from one section to another and upsetting the operation.

The accompanying photograph of the main generator board (ETI-166a), illustrates the general construction. A large 'groundplane' is on the component side of the board. Etched-out holes permit component leads to pass through to the track side. Some components have leads 'earthed' to the topside groundplane. The three shields are made from 15 mm wide strips of double-sided pc board soldered to the groundplane, separating the board into four sections. That on the far right contains the main oscillator (Circuit A) while the centre section contains the sine shaper (Circuit B). The section at the upper left contains the pulse generator (on Circuit D) while the small section at lower left contains two set trimpots and two bypass capacitors.

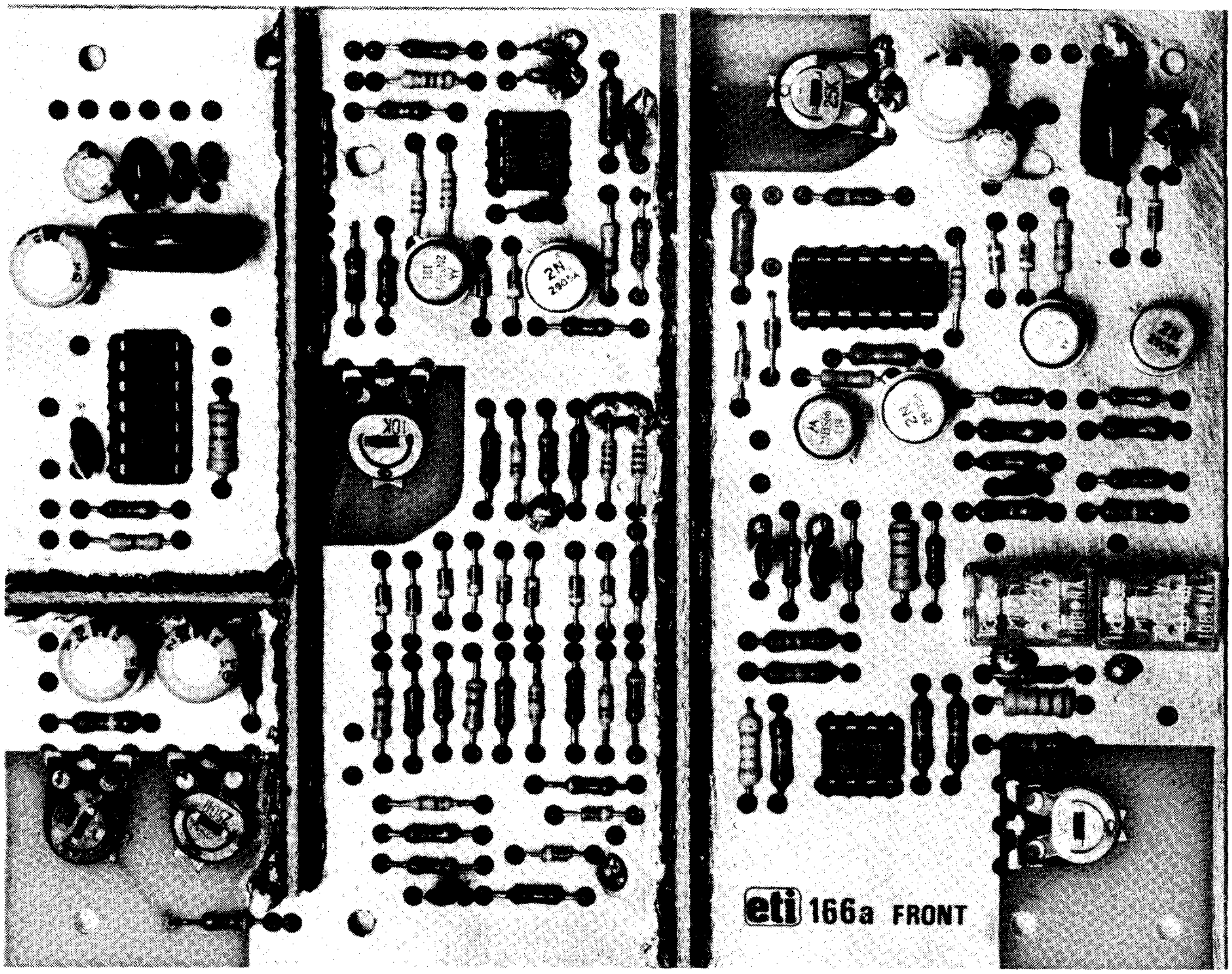
The frequency counter board (ETI-166b) is mounted above this board with long bolts and nuts to position it. All trimpots on the main generator board are still accessible, however. ▶



• DENOTES SOLDERED BOTH SIDES

ALL DIODES 1N914, 1N4148

Component overlay. Showing general assembly of the main generator board, ETI-166a. Note where shielded cable is used. Don't forget to link pin 7 of IC2 (BB-BC) to pin 3 of IC4 (BB). Use shielded cable. Pin 7 of IC2 also goes to the input of the Frequency Meter board (BC) — again, use shielded cable. Note the points soldered on both sides of the board. Some are linked by component leads, some by a tinned copper wire link. Note: C25, a 100n 'bluechip' ceramic should be soldered on the copper side of the board between pin 14 of IC4 and GND. Some relays may not match the board — in this event drill extra holes and wire in using links.



Main generator board. View of the completed ETI-166a main generator board. note the size and positioning of the shields. A number of top-to-bottom side links have to be installed before the shields are soldered in place (see text). To terminate the flying leads from this board, either pc stakes or short lengths of tinned copper wire are soldered in place in the appropriate positions.

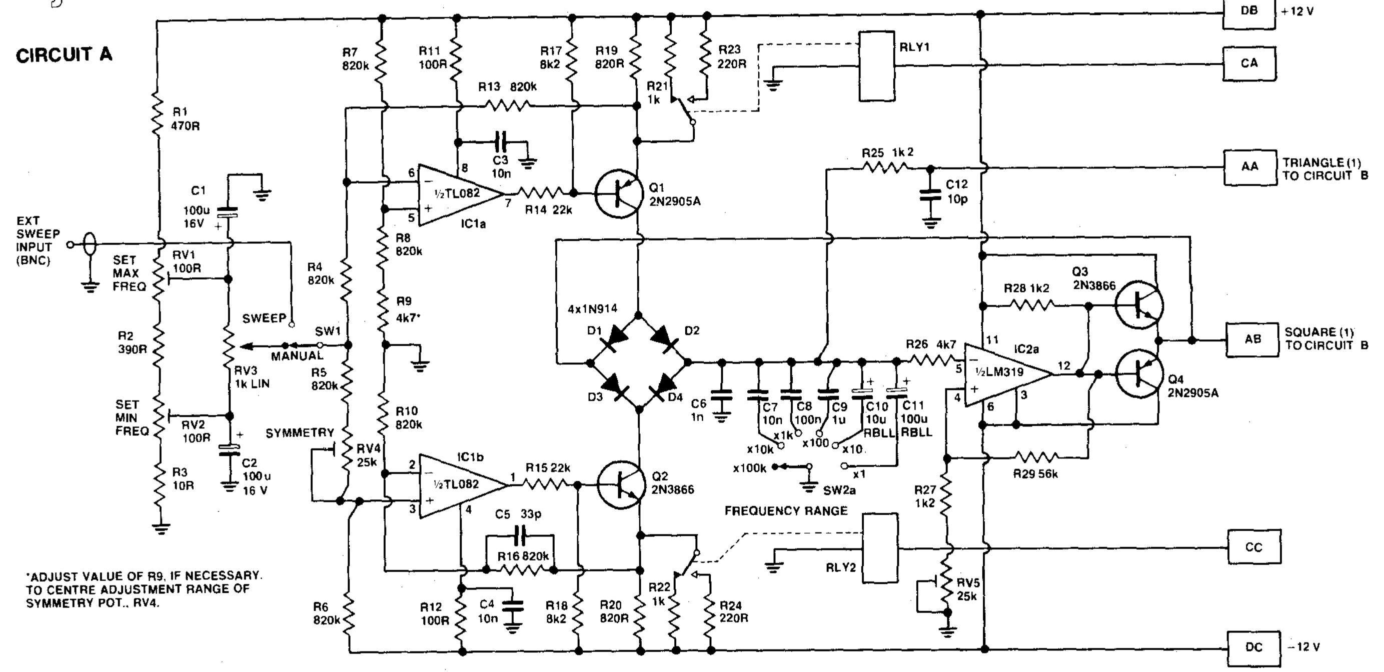
PARTS LIST — ETI-166a

Resistors	all ¼W, 5%
R1, 58, 59	470R
R2, R71	390R
R3, 35, 36, 56, 57, 60, 61	10R
R4, 5, 6, 7, 8, 10, 13, 16	820k
R9, 26, 30, 66, 73	4k7
R11, 12	100R
R14, 15	22k
R17, 18	8k2
R19, 20	820R
R21, 22, 34, 37	1k
R23, 24, 65	220R
R25, 28, 31, 72. 27	1k2
R29	56k
R32, 33	47k
R38, 39, 44, 45	2k2
R40, 41	2R7
R42, 46, 47, 70	10k
R43	6k8
R48, 49, 54, 55	39R
R50, 51, 67	330R
R52, 53	47R
R62, 63	22R
R64	270R
R68	120k
R69	39k
R74	2k7
R75	3k3
R76, 77, 78	47R
RV1, RV2	100R min. trimpot.
RV3, RV9	1k/A pot.
RV4, RV5	25k min. trimpot.
RV6	10k min. trimpot.
RV7	50k/A pot.
RV8	10k/A pot.
Capacitors	
C1, 2, 11	100µ/16 V RBLL
C3, 4	10n 'bluechip' ceramic
C5	33p ceramic
C6	1n greencap
C7	10n greencap
C8	100n greencap
C9	1µ/16 V tant.
C10	10µ/16 V RBLL
C12, 14	10p ceramic
C16	2n2 greencap
C13,15,25	100n 'bluechip' ceramic
C18	22p ceramic
C19	470p greencap
C20	4n7 greencap
C21	47n greencap
C22	470n greencap
C23	4µ7/16V RBLL
C24	47µ/16V RBLL
Semiconductors	
D1-D25	1N914, 1N4148
IC1	TL082, TL072, µA772
IC2	LM319, µA319
IC3	CA3100
IC4	74122 (see text)
Q1, Q4, Q6	2N2905A
Q2, Q3, Q5	2N3866
Miscellaneous	
SW1	SPDT min. toggle switch
SW2, SW5	two-pole, six-pos. rotary switch
SW3	two-pole, five-pos. rotary switch
SW4	one-pole, seven-pos. rotary switch
RLY1, RLY2	SPDT min. pc mount relays (e.g: D.S.E. S-7120)

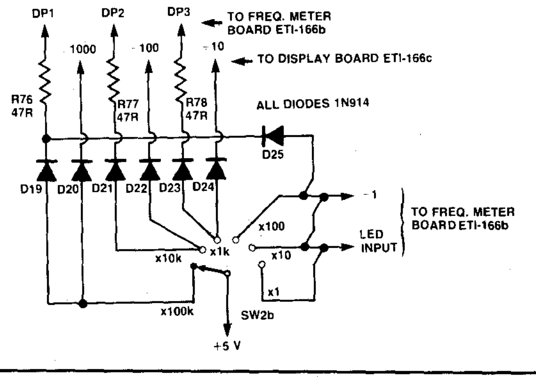
ETI-166a pc board; ETI-166b, c and d modules; ETI-1520 module; shielded cable; hookup wire, nuts, bolts etc.

Price estimate: $175-$185
(complete project)

CIRCUIT A



*ADJUST VALUE OF R9, IF NECESSARY, TO CENTRE ADJUSTMENT RANGE OF SYMMETRY POT., RV4.



HOW IT WORKS — ETI-166

I have divided the circuit into four sections, for convenience. Circuit A comprises the triangle wave generator, Circuit B the buffers and sine shaper, Circuit C the pulse generator, function select and output amplifier, while Circuit D comprises the power supply and frequency meter, described in Part 2 of this series. This should be read in conjunction with the block diagram given in Part 1.

CIRCUIT A

The triangle wave generator is built around a TL082 dual op-amp, IC1, a comparator from IC2 (an LM319) and a diode switching network, D1 to D4, plus associated components.

Two constant-current sources are used to charge and discharge a capacitor selected by the FREQUENCY RANGE switch, SW2a. The positive current source consists of IC1a, Q1 and associated components, while the negative current source consists of IC1b, Q2 and associated components. The inverting input of IC1a is tied to the non-inverting input of IC1b via R4, R5 and RV4. A voltage applied to the junction of R4 and R5 will vary current through the collectors of Q1 and Q2.

Now, the positive current source provides charging current for the capacitor selected by SW2a, while the negative current source provides discharging current for the capacitor. The rate of charge or discharge is determined by the current set to flow through the collectors of Q1 and Q2.

The capacitor selected by SW2a will charge via D2 until the voltage across it exceeds the upper threshold of the inverting input of IC2. Its output will then go low, turning Q4 on, its emitter 'pulling down' the cathode of D1, reverse-biasing D2 *and* preventing the capacitor charging current from flowing. The capacitor will then discharge via D4, at a rate determined by the current allowed to flow in the collector of Q2.

When the voltage across the capacitor reaches the lower threshold of IC2a's inverting input, IC2a's output goes high, turning Q4 off and Q3 on. This forward-biases D3 and reverse-biases D4, preventing the capacitor discharge current flowing any more. Charging current can begin to flow once again and the whole cycle is repeated as D1 is now reverse-biased, allowing D2 to permit current to flow into the capacitor from the positive current source.

As a voltage at the junction of R4 and R5 varies the current delivered by the current sources, varying this voltage will vary the frequency of oscillation. Hence, a resistive network can be used to provide frequency variations by a potentiometer, RV3 here, and setting of the maximum and minimum frequency limits.

The network R1, RV1, R2, RV2 and R3 form a simple voltage divider from the +12 V supply rail. RV3, the FREQUENCY SET control, is connected between the wipers of RV1 and RV2. Capacitors C1 and C2 are bypasses to keep hum and noise from modulating the current sources' input voltage and thus modulating the output frequency.

For a symmetrical triangle wave, the two current sources are virtually identical, the charge and discharge currents being the same. To produce a sawtooth wave, the charge and discharge currents are made unequal by means of a relay switching different value resistors in parallel with the emitter resistors of Q1 and Q2 accordingly. For a sawtooth that 'ramps up' then drops quickly to the start point, the discharge current is increased by the relay RLY2 switching from R22 to R24. Likewise, for a sawtooth that jumps up then ramps down, RLY1 switches from R21 to R23 to increase the charging current.

The triangle output is taken to Circuit B through a low pass filter, R25-C12, which removes high frequency switching 'rubbish'.

As you may have already realised, the waveform at the emitters of Q3 and Q4 is a square wave, this too, being passed to Circuit B.

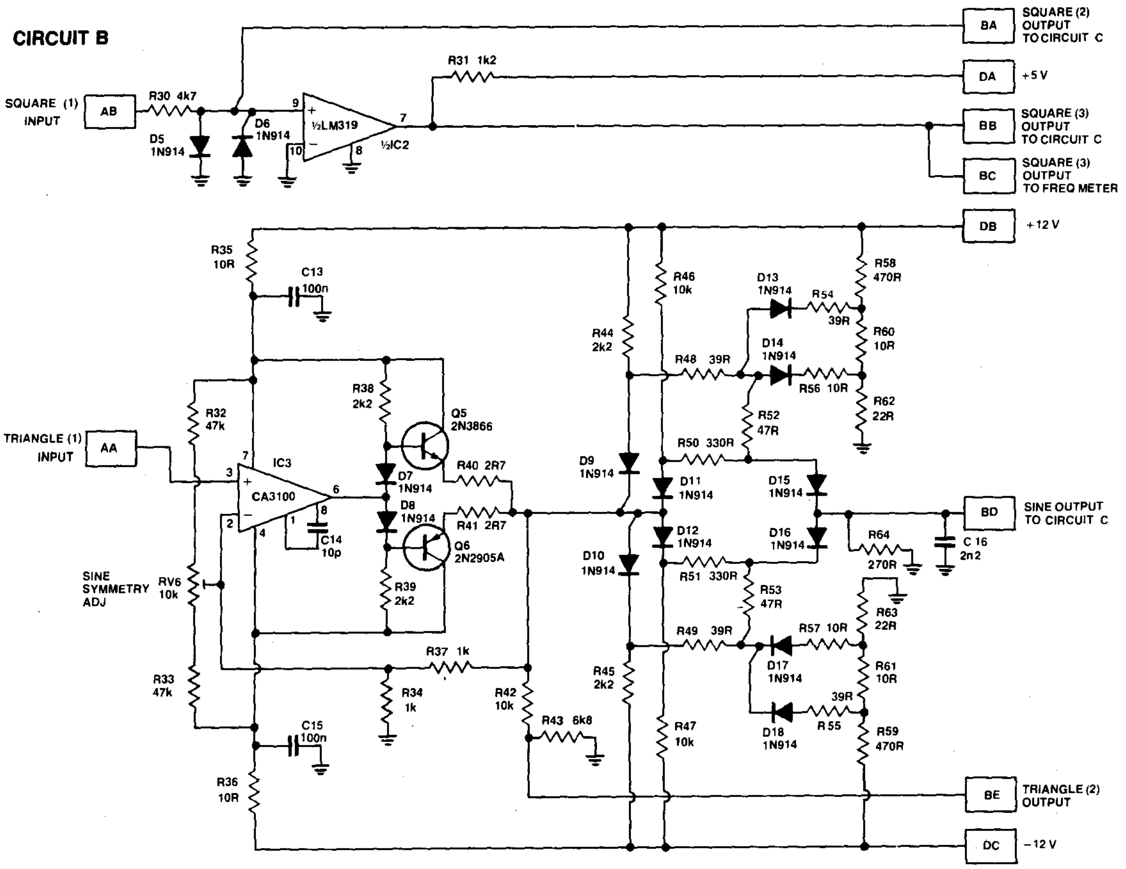
Note that the x100k frequency range capacitor is always in circuit, SW2a simply connecting the selected range capacitor in parallel. This cuts down on external wiring and reduces problems that might arise with stray inductance and capacitance at the high frequency end of the range.

The second half of SW2 is employed to switch the division ratios in the frequency meter and the decimal points in the display.

To make provision for external sweep, SW1 switches the current sources' input (junction of R4-R5) from the wiper of RV3 to the EXT. SWEEP input socket. Note that the external sweep control voltage can range from positive to negative owing to the symmetry of the current source circuits.

CIRCUIT B

There are two buffers in this section, and the sine shaper circuitry. The square input at AB is clipped by two back-to-back diodes, D5 and D6, producing a square wave with an amplitude of about 1.2 volts peak-to-peak. This is passed to the FUNCTION switch in Circuit C. It is also



applied to the non-inverting input of IC2b, the other half of the LM319, here acting as a squarewave buffer. As this has an open-collector output stage it can be used to drive TTL circuitry by using a pullup resistor from the +5 V rail, and that's the function of R31 here. The output of IC2 goes to the pulse generator input in Circuit C and also to the frequency meter input.

The triangle output from Circuit A is buffered by a stage similar to the output amplifier (ETI-1520 — Part 1). IC3, Q5 and Q6, plus associated components, provide a low impedance output, wideband buffer amp having a gain of two (determined by feedback resistors R34 and R37). The output of this buffer stage, at the junction of R40-R41, drives the sine shaper input. The sine shaper is a diode-resistor network that progressively changes the slope of the incoming waveform as it increases in amplitude, 'rounding off' the waveform to approximate a sinewave. It's too complex to fully describe here, but it works very well indeed.

The sine shaper output is taken from the junction of D25 and D26. A load is provided by R64 and the nominal output amplitude is 1.2 Vp-p. Capacitor C15 provides a little high frequency bypassing to remove high frequency switching rubbish. The sinewave output at BD is passed to the FUNCTION switch in Circuit C.

The triangle waveform at the buffer (junction of R40-R41) is attenuated to 1.2 Vp-p amplitude and also passed to the FUNCTION switch in Circuit C.

Construction

First do a visual check of the ETI-166a board. See that there are no broken tracks, holes incorrectly drilled or not drilled at all and that there are no tiny copper bridges between closely-spaced tracks.

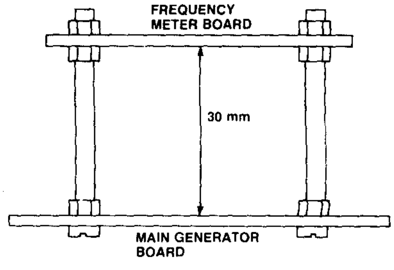
There are three top-to-bottom links to be soldered in. Identify these from the diagram and solder them in place first. Then, cut three shields to size and solder them in place, starting with the longest one. Hold the shield in position and 'tack' it in two places — on either side at each end. When it's in position, run a generous bead of solder down the joint along both sides. Use a hot iron with a large, wedge-shaped tip of about 4 mm width. A temperature-controlled iron is best for this sort of job. Don't overheat the board though or you'll risk lifting the copper. Do the next longest shield followed by the short one last of all.

The components can be soldered in place next, commencing with the resistors. Follow with the capacitors, making sure you get the electrolytics the right way round as shown on the component overlay. Take note of those components that have a lead soldered on the top side.

All the diodes can be soldered in place next, taking care that you correctly orientate them. Follow with the trimpots, then the transistors and ICs. If you wish, IC sockets may be used. Ensure that all the ICs and transistors are placed in the correct orientation. The transistors should be positioned such that the bottom of their cases sit only two millimetres or so off the board. Finish off by soldering the two pc mount relays in place.

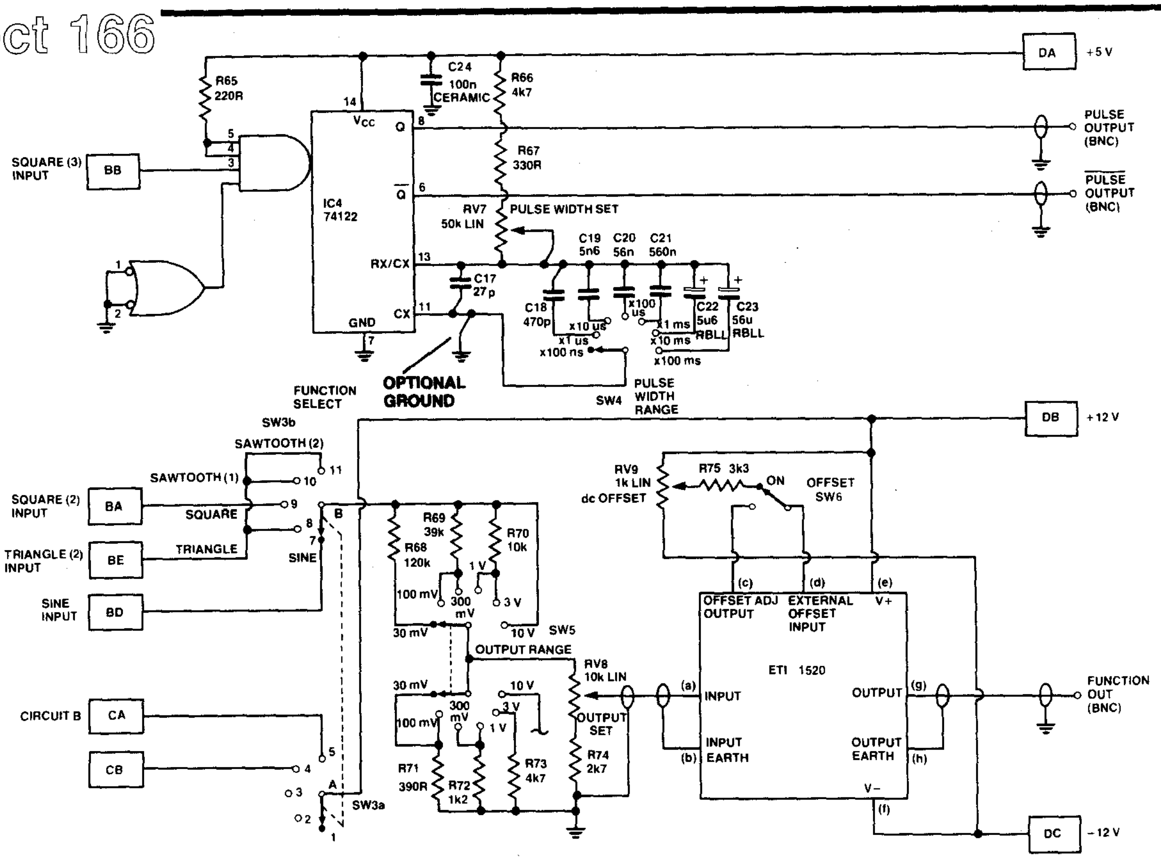
Having finished the board, carefully check *everything*.

Before proceeding, the four bolts that secure the frequency counter board (ETI-166b) should be assembled according to the accompanying diagram. ▶



Piggyback. The *ETI-166b* Frequency Meter pc board rides 'piggyback' on the main generator board, about 30 mm above it, using 40 mm long 6 BA bolts and nuts. the 16-pin DIL socket for the ETI-166c Display Board mounts toward the front panel.

CIRCUIT C



HOW IT WORKS — ETI-166

CIRCUIT C

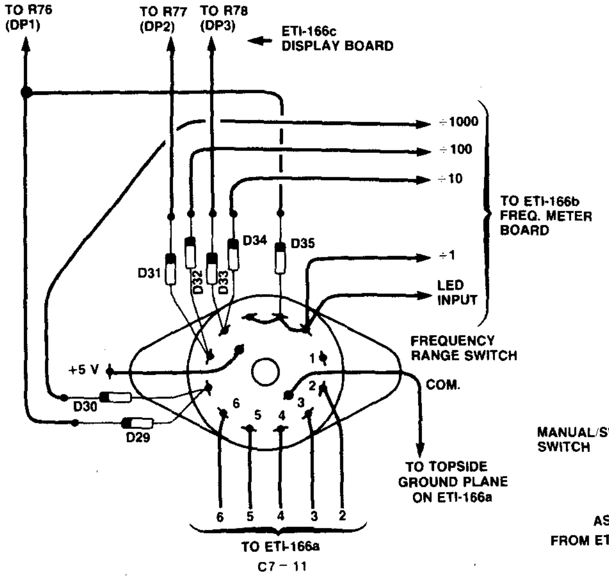
This section comprises the pulse generator, the FUNCTION switch, the OUTPUT RANGE controls and the output amplifier.

The pulse generator employs a 74122 dual monostable (IC4). Note that the 74S122 and 74LS122 can also be used here. The Q and Q outputs of IC4 go direct to the two PULSE output connectors. The PULSE WIDTH RANGE switch selects capacitors for the RC network that determines the output pulse widths. The resistance network R66-R67 and potentiometer RV7 provides the variation range for the pulse widths. Note that the x100ns range capacitor, C16, is always in circuit, the others being switched in parallel, the same as on the FREQUENCY RANGE switch. Some 74122s have to have pin 11 grounded, others do not. If pulse width 'jumping' occurs at some width settings, ground pin 11 of IC4.

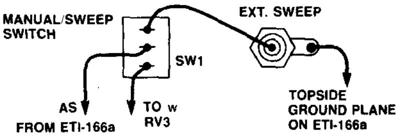
The FUNCTION switch, SW3, has two sections. SW3a selects the output required, while SW3b operates the two relays in Circuit A to provide the appropriate sawtooth output. Hence, the triangle input to SW3a is connected to three contacts.

All the signals at SW3a have a nominal amplitude of 1.2 Vp-p. The signal selected is passed to the OUTPUT RANGE attenuator, SW5. This is a straightforward voltage divider giving 1-3-10 step ratios. The OUTPUT SET potentiometer, RV8 provides continuous variation of the output down to a set low level, but not zero, as R74 is in series with RV8 to ground.

The output stage, described in Part 1, provides a gain of 20 dB, delivering a maximum output of 10 Vp-p. An OFFSET switch is provided, along with a DC OFFSET control (RV9).



Wiring SW2. How the FREQUENCY RANGE switch is wired up. The top of the front panel is toward the top of the page in this view.



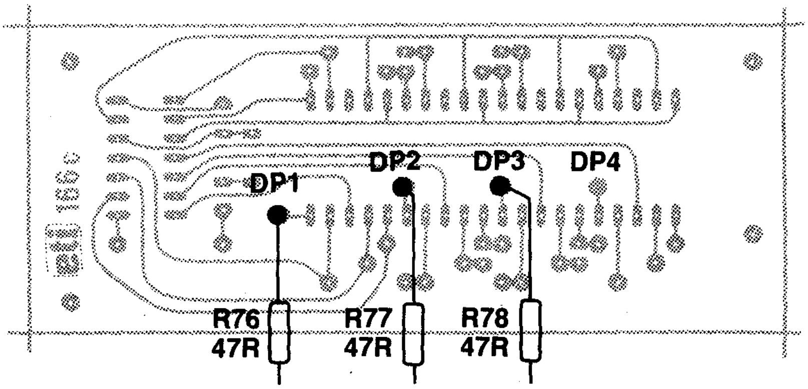
Sweep switch. Wiring SW1 and the EXT. SWEEP input.

Put the generator board aside and tackle the rest of the front panel assembly next. Install the three BNC sockets and the MANUAL/SWEEP switch first. The BNC sockets should be insulated from the panel using a grommet, as explained in Part 3. Don't forget to use earthing lugs as these are wired in with coax cable.

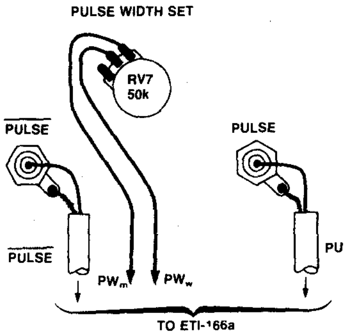
Mount the PULSE WIDTH SET pot. next, followed by the FREQUENCY RANGE switch. The FREQUENCY SET pot. and the PULSE WIDTH RANGE and FUNCTION switches can then be mounted. Don't mount the frequency meter display board yet, just to give yourself a bit more room to move for wiring up the components you've just mounted.

Now, seven diodes have to be mounted on the lugs of the FREQUENCY RANGE switch. This is shown in the diagram here. The wiring to the generator and frequency meter boards comes later. Next run a wire between the EXT. SWEEP input and the topmost lug of the MANUAL/SWEEP switch.

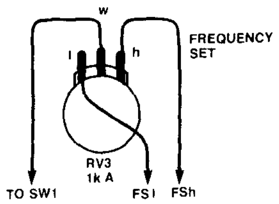
Go back to the generator and frequency



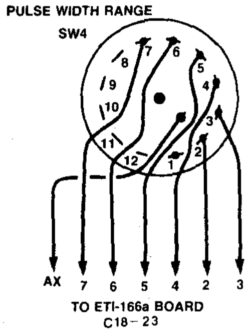
Decimal points. Resistors R76, R77 and R78 are soldered directly to the rear of the ETI-166c Display Board.



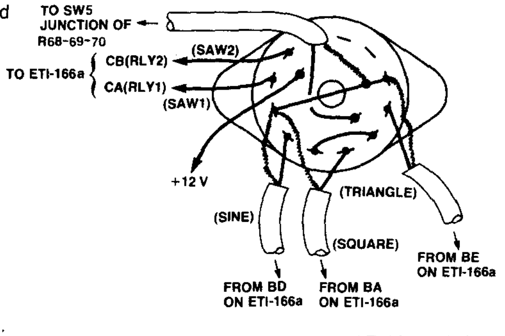
Pulse pieces. Wiring the two PULSE outputs and the PULSE WIDTH SET control.



Freq. set. Wiring the FREQUENCY SET control. Note that the wiper of RV3 goes to the lower contact of SW1, the MANUAL/SWEEP switch.



Wiring SW4. Showing the wiring from the PULSE WIDTH RANGE switch. Note that the top of the front panel is toward the top of the page in this view.



Function select. Wiring the FUNCTION switch, SW3. Note the use of shielded cable.

meter boards. Solder a pc stake or short length of tinned copper wire in every position requiring an external connection. Solder R76, R77 and R78 in position in the rear of the ETI-166c (display) pc board as shown in the accompanying diagram. Note that the CARRY output of the frequency meter (pin 14 of IC16 on ETI-166b) is not used here and no connection needs to be made to it.

Assemble the main generator board into the chassis. Start wiring it to the front panel components by connecting up the MANUAL/SWEEP switch. Follow by wiring up the two PULSE output sockets (use shielded cable). Then wire up the PULSE WIDTH SET pot., twisting its two wires lightly together. Then run the wires between the FREQUENCY RANGE switch and the board (SW2a), leaving the other half — which has the diodes already on it — till later. Wire in the PULSE WIDTH RANGE switch next, followed by the FUNCTION switch. Note where shielded cable is used. The FREQUENCY SET pot. can now be wired in and the power supply connections made.

The two frequency meter boards can now be mounted and wired in. Complete the front panel wiring and you're ready for testing and setting up your instrument. Before you do, *make another thorough check.*

Power up, set up

If you're confident all is well, plug in and switch on. The frequency meter display should immediately light up, settling down in a few seconds to show some frequency or other. Vary the FREQUENCY SET control and the numbers on the display should vary. Vary the FREQUENCY RANGE switch and note that the "Hz" LED lights when it's set on x1, x10 or x100, and the "kHz" LED lights when it's set to x1k, x10k and x100k. If you don't get the indications described, switch off and look for wiring errors.

If all is well, you can start setting it up. An oscilloscope is necessary for this. A noise and distortion meter would be desirable, but is not essential.

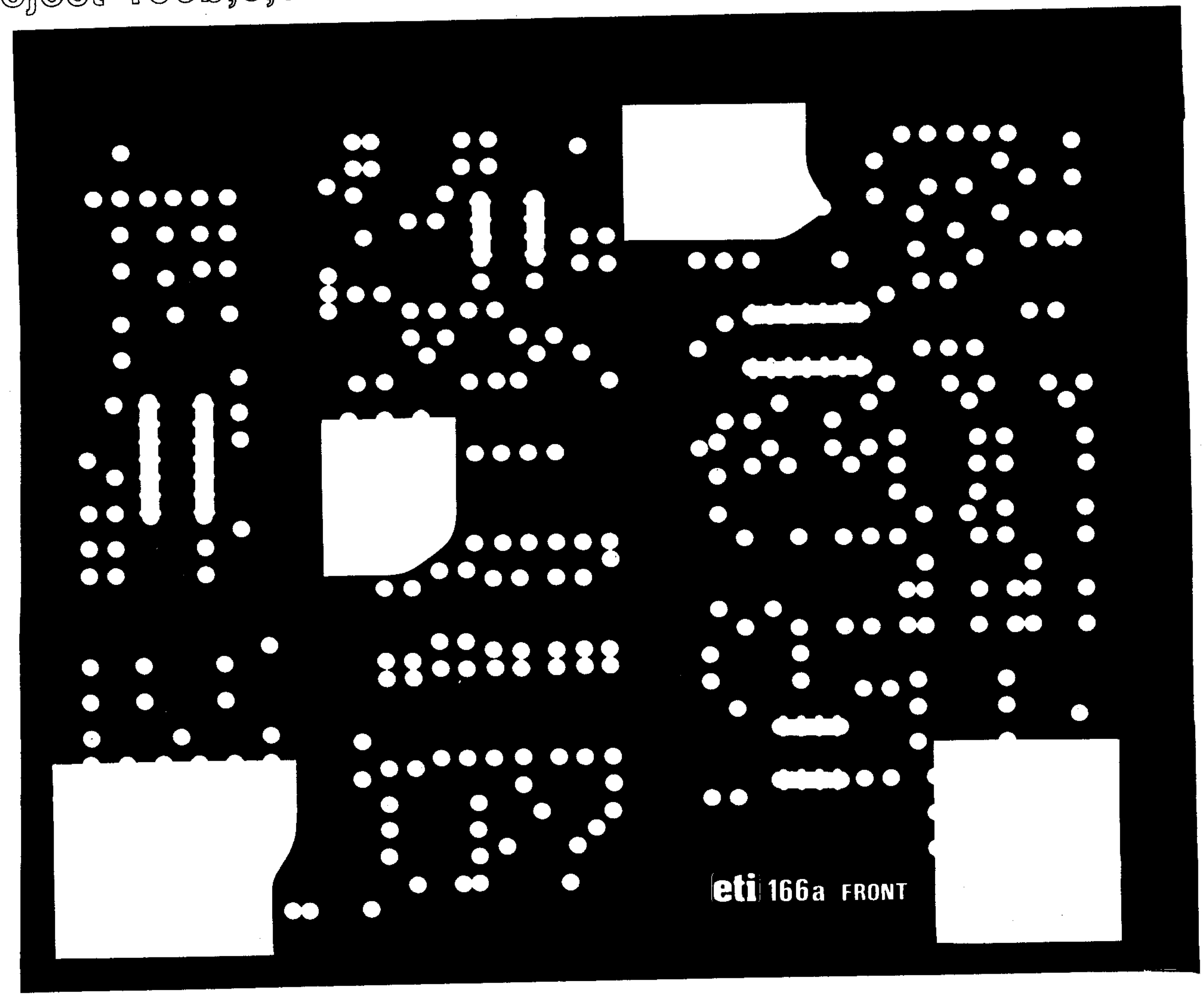
First of all, set the frequency range limits. The upper and lower frequency limits of any selected range are determined by just two trimpots — RV1 and RV2, located on the main generator pc board. Set the FREQUENCY RANGE switch to the x100 range and turn the FREQUENCY SET pot. to minimum (fully anti-clockwise). Adjust RV2 so that the display reads something less than 100 Hz, say 75 Hz, or thereabouts. Now swing the FREQUENCY SET pot. to maximum (fully clockwise) and put the FREQUENCY RANGE switch on x100k. Adjust RV1 so that the display reads something well over 1 MHz, such as '1100'.

Looking at the square wave on pin 9 of SW3 (FUNCTION), with SQUARE selected, adjust RV4 to obtain an equal mark-to-space ratio, then adjust RV5 so that the waveform swings symmetrically about 0 V.

Looking at the sinewave on pin 7 of SW3, adjust RV6 for the best looking sine curve (least distortion). If you have a distortion analyser, hook its input to pin 7 of SW3 and adjust RV5 and RV6 for least distortion (you should be able to get it to 2% or less).

Hook the CRO to the FUNCTION output and see that the output controls all work correctly. Note that the output cannot be reduced to zero as R74 prevents grounding the input of the ETI-1520 output amplifier stage. Check the two pulse outputs and see that RV7 works as it should. If the pulse width suddenly decreases as you wind RV7 clockwise, then pin 1 of IC4 (the 74122) should be grounded. Provision for this has been made on the pc board.

Run through all the frequency ranges, checking the waveform outputs and controls. Take a close look at the peak of the triangle wave. If, on any range, you get a 'step' on the 'down ramp' side of the peak, then change the corresponding frequency range capacitor (capacitors C6 to C11). This is caused by too high an internal inductance in the component. You may get a low level 'spike' at the peak of the sine waveform, but it should be of little consequence. ●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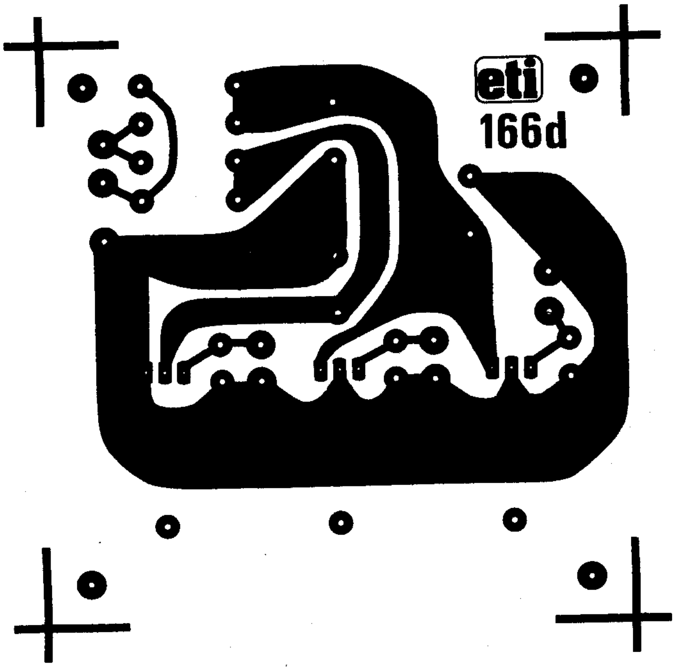

eti
166d

Wideband amplifier module

Here is a wideband amplifier capable of driving a 50 ohm load with an output capability of 10 volts peak-to-peak. It has many applications, e.g: improving the sensitivity of a CRO or a counter, as a video amplifier or boosting the output of a signal generator.

David Tilbrook

THIS PROJECT is, in effect, the first part of the ETI-166 Function Generator, the remainder of which is published elsewhere in this book. This section of the project is presented apart from the main project so that it can be made as a separate self-contained unit. It is suitable for any application needing a low distortion, wideband amplifier, such as a transmission line driver or video amplifier.

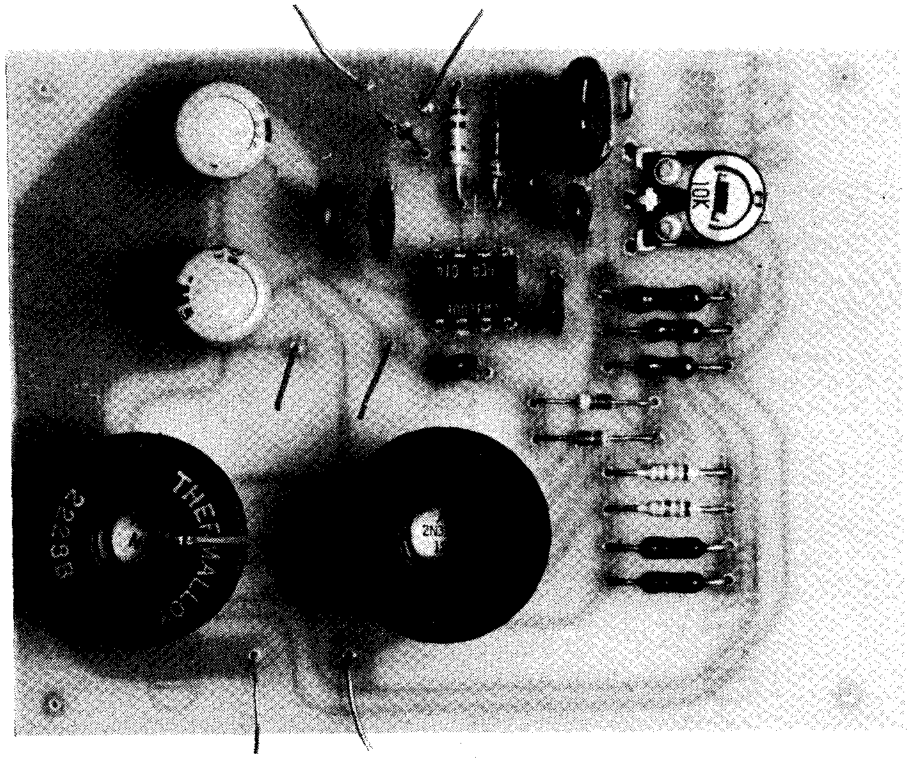
In the Function Generator this project is used as the output amplifier since its wide frequency response and 50 ohm output impedance enable it to provide large signal level sine and triangle waves (up to around 8 V peak on a 12 V supply) to a broad range of load impedances.

In order to keep both the design and the construction relatively simple it was decided to use an integrated circuit, if possible, to form the basis of the project. The main problem was to find a device capable of the necessary speed.

In order to produce a 10 V peak-to-peak triangle wave at a frequency of around 1 MHz, a slew rate of approximately 30 volts/microsecond would be a necessary minimum. Although this is not beyond the capability of a number of high speed operational amplifiers, some of these devices achieve a high slew rate by means of a relatively complicated 'feed forward' technique which can make the device prone to instability on some types of load. Furthermore, some of these devices have poor gain at high frequencies even though their slew rate figures are good.

After a look at the devices available, the CA3100 wideband op-amp was chosen. This device is manufactured by RCA and is almost ideally suited to this application. It combines both high slew rate and good gain at high frequencies. It is also convenient to use since it has a standard op-amp pinout.

The output drive capability is, of course, not sufficient but this is easily solved by following the op-amp with a unity gain emitter follower stage. This results in a general purpose wideband amplifier capable of driving a 50 ohm load and having a slew rate around 40 V/us. The bandwidth of the circuit is approximately 15 MHz for a 1 V RMS output signal level.



SPECIFICATIONS ETI-1520 WIDEBAND AMP MODULE

Gain	9.2 x (approx. 20 dB) depends on R4		
Maximum output voltage swing	10 V peak-to-peak into 50 ohm load with +/−15 V supply (20 Vp-p no load)		
Frequency response before slew rate limiting (power bandwidth)	dc — 1.3 MHz (20 Vp-p output) dc — 2.2 MHz (10 Vp-p output) dc — 4.5 MHz (5 Vp-p output) (below 5 Vp-p output, feedback limits top end frequency response)		
Frequency response	dc — 5 MHz +0, −3 dB dc — 13 MHz +0, −10 dB dc — 30 MHz +0, −20 dB		
Distortion (at 1 V RMS output)	@ 20 Hz 0.03%	@ 1 kHz 0.03%	@ 20 kHz 0.03%
Noise (20 kHz bandwidth)			
Input terminated by 1k	10 nV/ Hz		
Input short circuited	8 nV/ Hz		
Current consumption +/−15 V supply rails)	25 mA (no load)		

Since the amplifier is dc coupled, a dc offset control has been included to enable the output dc level to be set to any voltage required.

In the *ETI-166* Function Generator the output dc level is adjustable by means of a front panel potentiometer and this is accommodated using the optional dc offset input provided on the amplifier.

If this is not required in a specific application the on-board dc offset preset can be selected by fitting the appropriate link on the pc board.

Construction

Construction is fairly simple using the ETI-1520 pc board layout. Since relatively high frequencies are encountered, the layout and construction will affect performance. For this reason, an IC socket should not be used. The pc board layout should not be altered unless you have access to the test equipment required to ensure that performance has not been degraded.

Commence construction in the usual way by soldering the resistors and capacitors in place first. Be careful to orient C4 and C5 correctly since these are electrolytic capacitors. Keep all lead lengths as short as possible.

Solder the diodes, transistors and the IC in place, again ensuring that these devices are inserted with the correct orientation. Pin 1 of the IC is shown on the diagram accompanying the main circuit diagram.

A diagram showing the pinout of the transistors has also been included. The emitter of these devices is the pin closest to the metal tag on the case of the device.

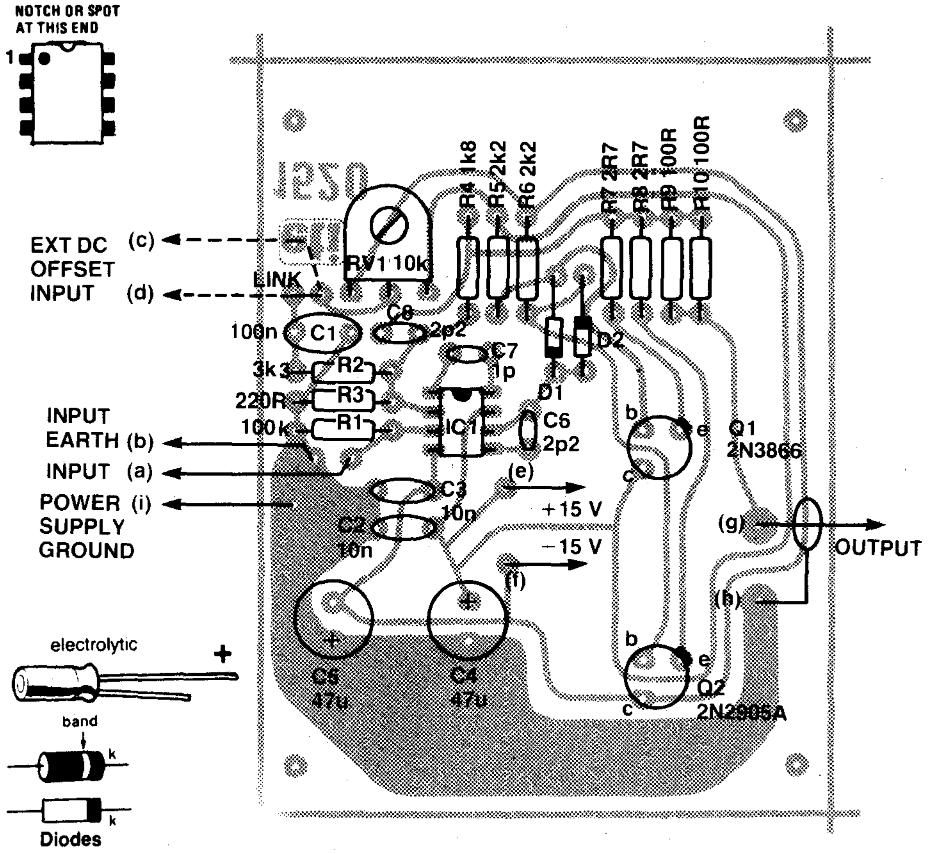
If the internal dc offset preset is to be used solder this in place after bending the leads so that the preset will lie flush against the pc board. Fit a link as shown on the component overaly to select the preset.

Once all the components are soldered correctly make a final check of the orientation of all polarised components. If all is well connect a ±15 V supply and power up.

Usually the dc offset will be required to be zero to ensure maximum output signal level and symmetrical clipping. Connect a voltmeter between the output and earth and adjust the offset pot so that the dc voltage on the output is zero.

The amplifier will work correctly on lower supply voltages than the ±15 V recommended, except that slew rate and frequency response are decreased. The RCA data sheet includes a curve showing the relationship between open-loop bandwidth and supply voltage (see opposite page). The supply voltage should not be allowed to increase above ±15 V since this is the maximum voltage recommended for the op-amp.

If the amplifier is to be operated from the same supply as other circuitry, ensure that the supply is reasonably free of noise. Although the amplifier has supply decoupling capacitors on the pc board most devices responsible for noise on supply lines tend to have low source impedances.



PARTS LIST — ETI-1520

Resistors	all ¼ W, 5% unless noted
R1	100k
R2	3k3
R4	1k8
R5,R6	2k2
R7,R8	2R7
R9,R10	100R, ½ W
RV1	10k vert. mount trimpot
Capacitors	
C1	100n greencap
C2,C3	10n ceramic
C4,C5	47u/25 V single-ended electro.
C6	3p3 ceramic
C7	1p ceramic
C8	10p ceramic
Semiconductors	
D1,D2	1N914
IC1	CA3100E
Q1	2N3866
Q2	2N2905A

Miscellaneous
ETI-1520 pc board; transistor heatsinks — Thermalloy 2228B or similar (if needed).

Price estimate $12-$15

The noise generators are therefore capable of charging and discharging the filter capacitors at the frequency of the noise. Increasing the value of the capacitors is usually ineffective since a very large increase is usually required.

The only effective solution is to increase the source impedance of the noise generators, and this is best done by fitting small value resistors in series with the supply lines. These resistors have not been included on the pc board since the value required (if they are required at all) is determined entirely by the particular application.

A good choice for most applications would be around 3R3, producing only a 1 V drop at the maximum possible output current. This value may be insufficient if the supplies are extremely poor. In most cases these resistors will be entirely unnecessary and should only be used if a definite problem exists.

In some applications it may be necessary to fit the output transistors with small heatsinks. If, for example, the amplifier is used to drive a 50 ohm load at low frequencies the instantaneous power dissipation in the output transistors will be around 1 W and a small heatsink should be used.

The best way to determine if a heatsink is required is to power up the unit and check the temperature of the output transistors. The transistor cases should be kept at a temperature that is comfortable to touch, and this will correspond to around 40 or 50 degrees Celsius.

HOW IT WORKS ETI-1520

The project employs a wideband, high-speed op-amp (IC1) operated from split supply rails, followed by a unit gain emitter follower stage (Q1, Q2) that provides some output current gain so that the amplifier can drive low impedance loads.

The op-amp chosen is a CA3100. Input signals are applied to its non-inverting input via terminal (a). R1 determines the overall input impedance. The output of the op-amp, pin 6, drives the emitter follower output stage. As split supplies are used, a complementary pair of transistors is employed, Q1 and Q2. Diodes D1 and D2 maintain a potential of about 1.2 V between the bases of Q1 and Q2.

As pin 6 of IC1 swings positive Q1 turns further on and Q2 turns further off and the output voltage goes toward positive. As pin 6 of IC1 swings negative, Q2 turns further on, Q1 turns further off, and the output voltage goes toward negative.

Resistors R5 and R6 provide a small amount of bias for the emitter follower stage, while resistors R7 and R8 ensure current sharing between Q1 and Q2. Resistors R9 and R10 establish the output impedance at 50 ohms.

Overall feedback is provided by R4 and R3 and the gain is equal to:

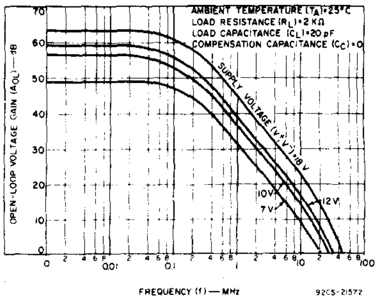
$$(R4 + R3)/R3$$

If you need to increase the gain, increase R4. Capacitor C8 provides frequency compensation in the main feedback loop. Capacitor C7 provides phase compensation for the op-amp for overall stability, while C6 provides a little negative feedback at high frequencies to ensure high frequency stability.

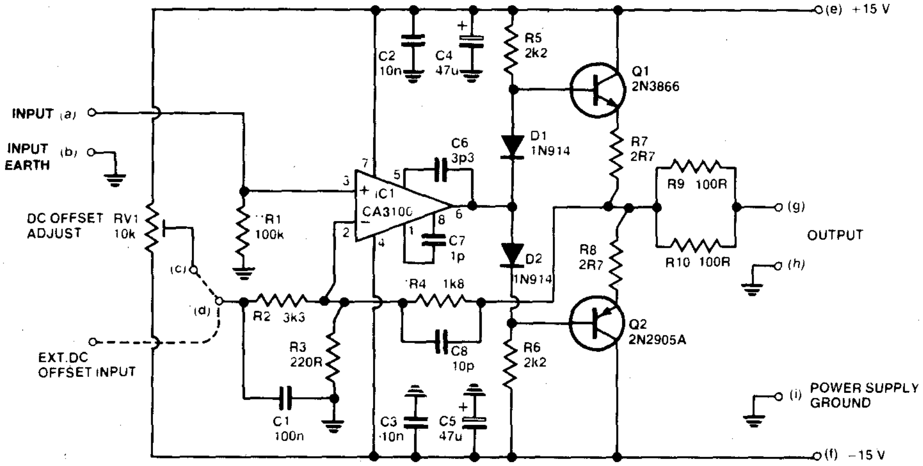
To provide dc offset adjustment, a small bias voltage is applied to the op-amp's inverting input via R2. This can be obtained on-board or off-board.

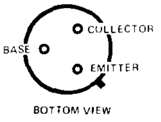
On-board dc offset is provided by linking terminals (c) and (d). This connects the wiper of RV1 to R2. Thus, adjusting RV1 will adjust the output dc offset voltage. Capacitor C1 is a bypass for this input.

Supply rail bypassing is provided by a 10n ceramic capacitor on each supply line, near the op-amp, and a 47u electrolytic capacitor on each supply rail.



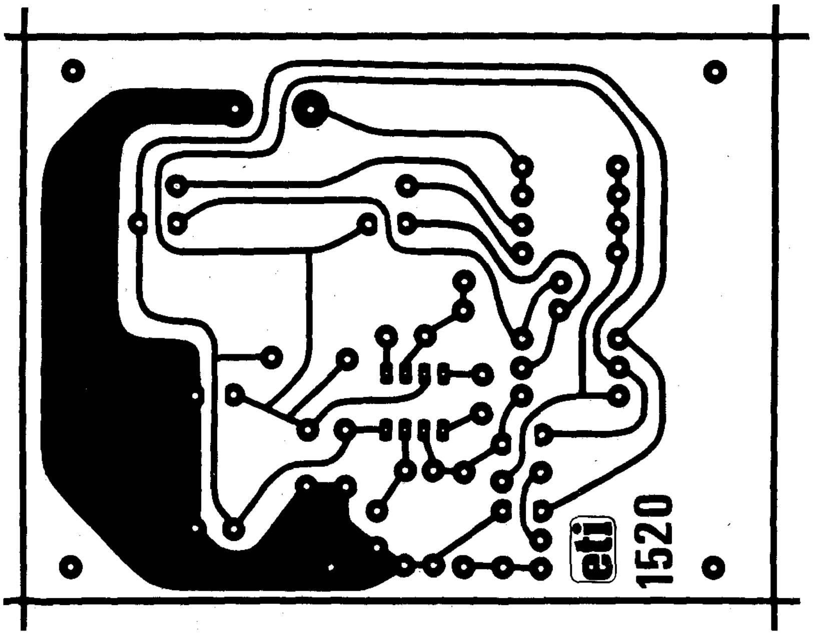
Performance. Open-loop gain versus frequency for the CA3100.



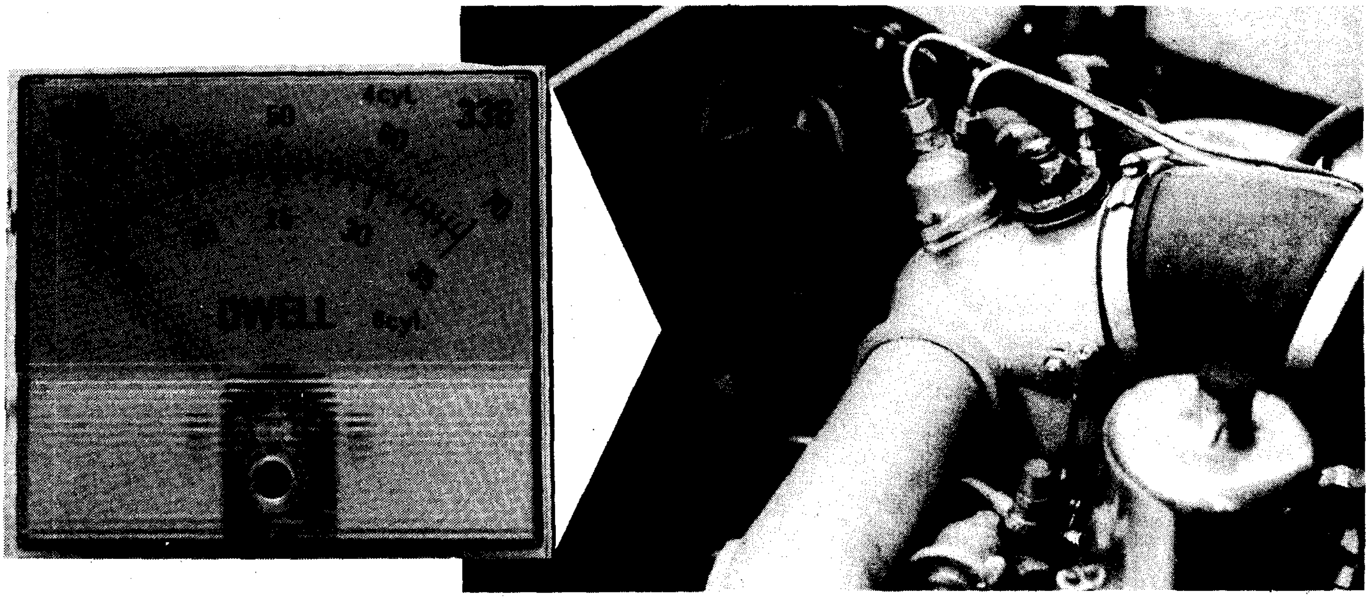


Q1 Q2

Note: There is a discrepancy between the values of C6 and C8 shown on the component overlay and this circuit (and Parts List). The values shown here (and in the Parts List) are correct.



Project 336



Low-cost dwell meter for vehicle tune-ups

You can do your own vehicle tune-ups at home and save the cost and inconvenience of sending it to the garage. Just about the most useful device you could have is a dwell meter. They can be bought 'over the counter', but you save even more money and increase your personal satisfaction by building your own.

Jonathan Scott

THE FACT THAT you've started to read this article means you probably know quite well what *dwell* is, and the advantages of owning a dwell meter, rather than letting your regular mechanic do the adjustment periodically. (If not, please see the section explaining dwell in automotive ignition systems, because that is where the automotive content of this article is dealt with.)

You are possibly also aware that one can readily buy a tacho/dwell meter in local automotive or electronic shops for around $25-$30, which is marginally more than the cost of this project, box and large meter included. So why describe a project that merely reads dwell?

The reasons are threefold: First, if you have ever dissected one of the commercial units, you may be aghast to note the lack of any transistors — often they rely on diodes alone, and a few quarter-watt resistors on a small board. The circuit, though ingenious, is rather simple and does not inspire this author to praise the accuracy or long term stability.

This project, once calibrated carefully (emphasis on this, as there are pitfalls, outlined later), will be as good as the components you use, which is comparatively very good. In addition, if you have built the thing yourself, it is easy to repair should anything go wrong, from a blown transistor to a crushed meter, and there is a good chance of that if you throw it around like other car tools.

Secondly, this project can be quite cheap. The major expense is the meter, so if you wish to build it as an addition to a multimeter and house it in something cheap, or not at all, it becomes very economical. None of the components is critical, except those resistors specified as high-stability types (readily available these days), so it can be a junk-box job if you need.

All you require in addition is a microamp-to-degrees conversion scale (see later) and you're away.

A second advantage occurred to me as I wandered from car to car, testing the prototype. The board is sufficiently cheap that you could leave one connected permanently to the car (it does not affect the running) and, if you are into stacks of dials on your dash, have another one!

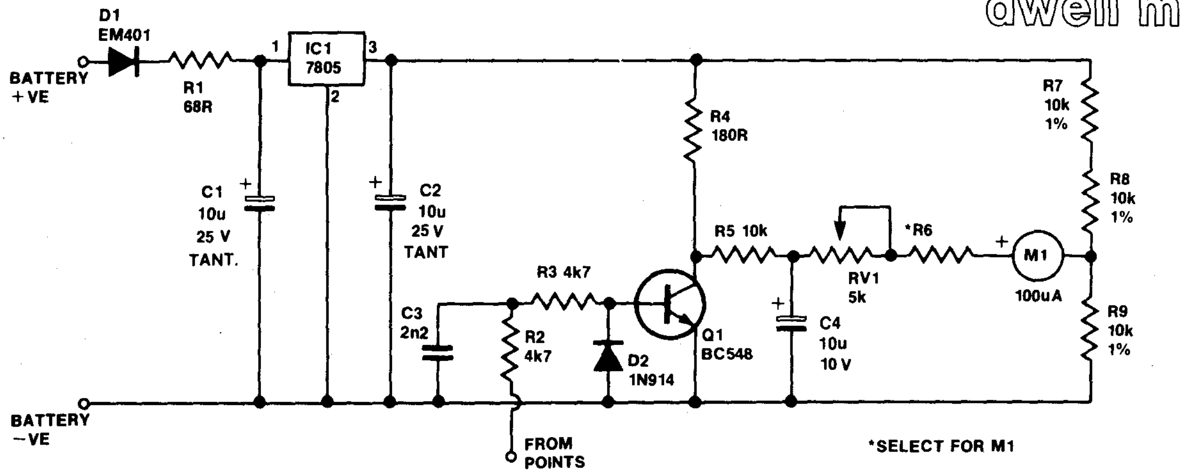
Finally, many cars have tachometers of the electronic genre already, and offer more accurate rpm indication than the cheap commercial tacho/dwell units anyway. If you have such a car, there is no incentive to have a second tachometer function which clutters up the scales, etc.

If you want to add a tachometer function to the dwell meter circuit described here, it is an elementary task to fit the circuitry of one of our previous projects in the same box, using the same meter which, as I have said, is the major cost of the whole thing.

Having justified the usefulness of this design, let's get on with it!

Construction

Construction of the Dwell Meter is very straightforward. The first step, if you are going to mount it in a case, is to cut the



HOW IT WORKS — ETI 336

The dwell meter is simply a 'duty cycle' meter with a zero offset and suitable scale markings on the meter face. It measures the closed-to-open ratio of the vehicle points.

Referring to the circuit diagram, D1 and R1, in conjunction with IC1, provide a reverse polarity protected +5 volt supply from the car battery. Capacitors C1 and C2 remove interfering pulses and ensure that IC1 remains stable.

The square wave voltage created by the 'points' opening and closing is filtered to remove the inductive 'spikes' by R2, R3 and C3. Diode D2 protects Q1 from negative voltages which may appear at the input. The square wave is then inverted and set to a fixed amplitude by Q1, which alternately turns hard on (saturates) and cuts off as the points open and close, respectively.

The average voltage appearing on the collector of Q1 is thus proportional to the time the points spend closed, ranging from almost zero for open points to +5 volts when the points are closed. Resistor R5 and capacitor C4 filter this square wave to reveal a relatively steady level. Meter M1 and surrounding components are set to give a minimum scale reading of 33 % and a FSD reading of about 78%. This corresponds to a range of 30-70 for four cylinder engines, 20-47 for six cylinders, 15-35 for eight, 24-56 for five 10-23 for twelve, etc. It is simple to calculate the duty cycle given the formula:

% duty cycle = (Degrees of Dwell) x (No of cylinders) x (100/360).

Resistor R7 is selected to allow for the internal resistance of the meter. The meter type used in the prototype had a resistance of about 1800 ohms. The sum of meter resistance and R7 should equal a little under 3000 ohms. The trimpot, RV1, is set to calibrate the meter full-scale deflection (FSD). Meter zero is held correct by the resistors R7, R8 and R9 which provide an 'offset' voltage.

Without the points connected, the meter needle goes to full scale as the positive terminal is returned to +5 V via R4, R5, RV1 and R6, while the negative terminal is at a lower voltage via the R7-8-9 voltage divider. This will not damage the meter.

meter mounting holes. Once you are satisfied that the case is prepared, check the printed circuit board to ensure that the holes on it are of a suitable size. If you intend to mount the board on the rear of the meter itself, as I intended, ensure that the meter connection holes are large enough to fit the meter posts.

Once prepared, mount the components on the pc board, taking care to orientate the IC and other semiconductors correctly. Also check that the electrolytic and tantalum capacitors are the correct way around. Reversing C4 could produce devious and subtle problems! While attaching the components, tin the copper areas around the meter mount holes so that the meter post nuts make good contact on to ▶

DWELL IN AUTOMOTIVE IGNITION SYSTEMS

The distributor in the standard type of car has two functions. First, it 'distributes' the spark energy from the ignition coil to each spark plug in turn by means of the rotor and cap of the assembly. This is the most obvious job of the distributor, and the one from which it gets its name. But it is not the most critical, or the one requiring the most attention and adjustment.

It also contains a mechanism for opening and closing the points, which interrupt the ignition-coil primary current and generate the spark itself.

These points are subject to considerable wear and, as they affect both the spark strength and its timing, they are perhaps one of the weakest links in the ignition system.

The lower assembly of the distributor must open and close the points **once** for each cylinder for each **two** revolutions of the main engine shaft. Each time it is responsible for ensuring that the coil has enough time to build up primary current, and that the opening occurred at the correct moment, accounting for engine RPM and possibly also the degree of vacuum fed to it down a small pipe from the inlet side of the engine carburettor.

The two functions which must be adjusted are **dwell** and **timing**. These are analogous to the duty cycle and phase of the square wave (current) generated by the regular opening of the points. Dwell actually means the amount of time, per revolution of the distributor shaft, which the points spend closed.

Timing means the relative phase, referred to the moment when the piston is at the position of maximum compression (top dead centre or 'TDC'), of the moment of delivery of the spark energy. The latter can be set statically by aligning marks at various positions, and the former by judicious use of feeler gauges on the points, but neither method is as accurate as the electronic methods.

A stroboscope is used for the timing adjustment, and a duty-cycle meter, called a dwell meter, with special scales, is used for the dwell measurement.

Dwell is specified, not by the kind of figure that an electrical engineer would expect — namely a % duty cycle or a number of electrical degrees — but by the actual number of mechanical degrees traversed by the distributor shaft while the points are closed.

Thus, although the actual duty cycle may be similar in all engines, irrelevant of number of cylinders, the degrees of dwell specified appears to change with the number of cylinders. This is because the distributor must deliver one spark for each cylinder in each 360 degrees of revolution.

A four-cylinder car has 90 degrees (360/4) of revolution, so a specified figure of 50 degrees of dwell means 50/90 or 56% duty cycle. A 12-cylinder car has only 30 degrees per cylinder, so 17 degrees of dwell means about the same duty cycle.

Clearly, it is possible to convert any quoted dwell figure into duty cycle by knowing the number of cylinders, then a universal scale of duty cycle on a duty cycle meter would suffice. However, it is usual practice to have several scales on the meter face to achieve the same thing.

Also, since doubling the number of cylinders merely means that the scale reads twice the actual mechanical reading, scales for four and six cylinders enable easy use on eight- and 12-cylinder cars, merely by halving the read value.

Equations for converting dwell into duty cycle and vice versa are given in the 'How it Works' section, so if you happen to have an engine with an unusual number of cylinders you may construct a scale for yourself, or convert the manufacturers specified dwell for, say, a five-cylinder car into what the meter will read on the scale for a four-cylinder car.

the board. If you do not do this, the lacquer put on the pc board to stop corrosion could insulate the meter posts completely.

Connect lengths of hookup wire to the battery and points connections. These will be led out of a hole in the case, and alligator or other suitable clips attached to them for connection to the car electricals.

Next fit the meter in the case, then fit the pc board to the meter, leaving the trimpot accessible. Final assembly should be left until the calibration has been completed.

Calibration

A known calibrating signal will be required to set up the meter. It is not advisable to use a sinewave source (such as from a low-voltage mains transformer) as this can introduce some error. A square waveform is desirable. This must be of known duty cycle. If you have a signal generator which delivers a known duty cycle square wave, typically 50%, set it to deliver 10 to 30 volts peak-to-peak output, and adjust the trimpot for the correct reading.

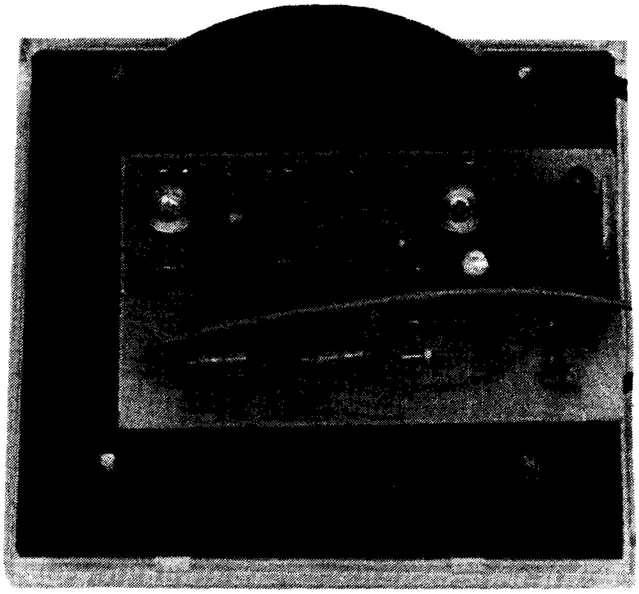
The calibrating signal must have a duty cycle of between 40% and 78%. The higher the better, for accuracy.

If you do not have access to a suitable source, proceed as follows. You will need a sinewave of between 20 and 50 volts peak. If you have a transformer delivering nominally between 7 and 20 volts RMS, it will do nicely. Connect the transformer to put the full ac voltage between the 'batt-' terminal and the 'points' input. Adjust the trimpot for a reading of 50% duty cycle, or 45° dwell on the four-cylinder range. If an oscilloscope is available, it may be used to check the duty cycle at the collector of Q1, and the trimpot used to set the meter to agree with the measurement taken by the oscilloscope. The frequency of the input is not important, of course, provided it is less than a few hundred Herz. (The mains is 50 Hz.)

Using it

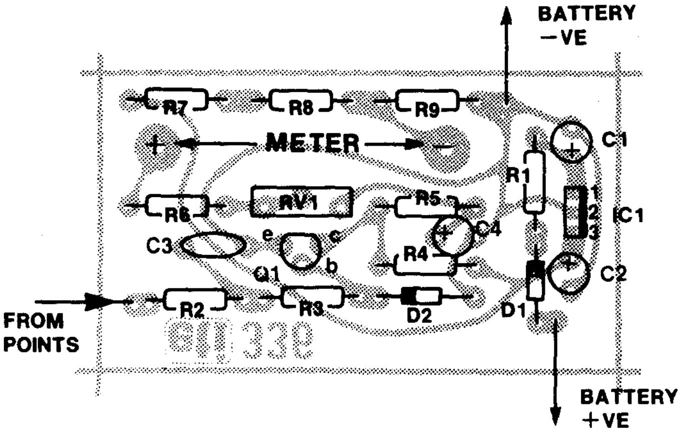
Use of the dwell meter, if you have never used one before, is elementary. Simply place the meter in a convenient location near the engine bay. Note that the typical panel meter changes its calibration when it is moved from the horizontal to the vertical, *so it should be used in the position in which it was calibrated initially.*

Connect the 'batt+' lead to the car battery positive terminal, and the 'batt-' lead to the battery negative connection. Connect the points lead to the junction of the ignition coil and the points in the distributor. When the car is running the meter reads dwell. Adjustments should be made according to the manual for the particular car, but in an emergency all cars are likely to have dwell specifications which lie roughly at the half-scale point on the meter. ●

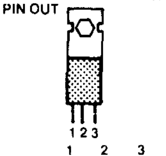


Rear view. The board mounts directly on the terminals of a University TD-86 meter. On other types, use heavy-gauge tinned copper wire to secure the board to the meter terminals.

See Shoparound in this issue for suppliers of kits and components for this project.



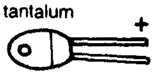
VOLTAGE REGULATOR PIN OUT

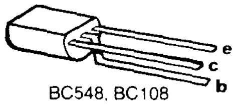


	1	2	3
78XX	IN	0 V	OUT
79XX	0 V	IN	OUT

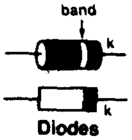
Capacitors

tantalum





BC548, BC108



Diodes

PARTS LIST—ETI 336

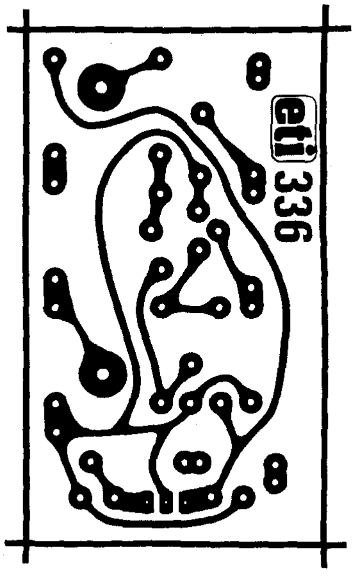
Resistors	all ¼W, 5% unless noted
R1	68R
R2, R3	4k7
R4	180R
R5	10k
R6	1k selected, see text
R7, R8, R9	10k 1% or 2%
RV1	5k min. trimpot
Capacitors	
C1, C2	10u/25V tantalum
C3	2n2 greencap
C4	10u/10V single-ended electro.
Semiconductors	
D1	EM401, EM402, 1N4001, 1N4002 etc
D2	1N914, 1N4148 etc
IC1	7805 or 78L05 etc
Q1	BC108, BC547/8/9 etc
Miscellaneous	
M1	100uA panel meter, e.g: Minipa MU-65, University TD86

ETI-336 pc board; case to suit; three alligator clips; hookup wire; meter scale to requirements, etc.

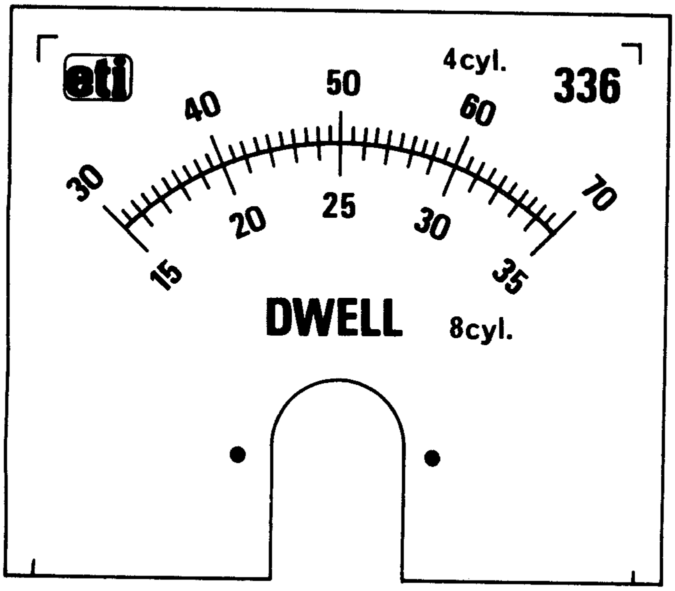
* R6 selected so that R6 + meter resistance equals a little under 3k.

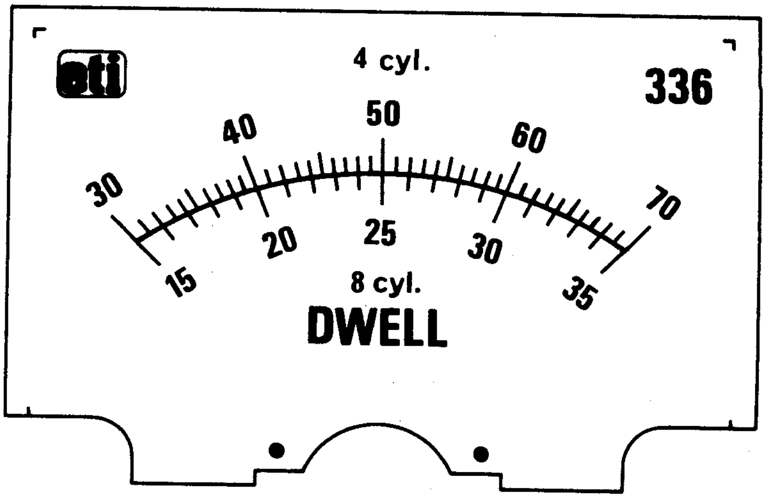
Estimated cost: $16-$24

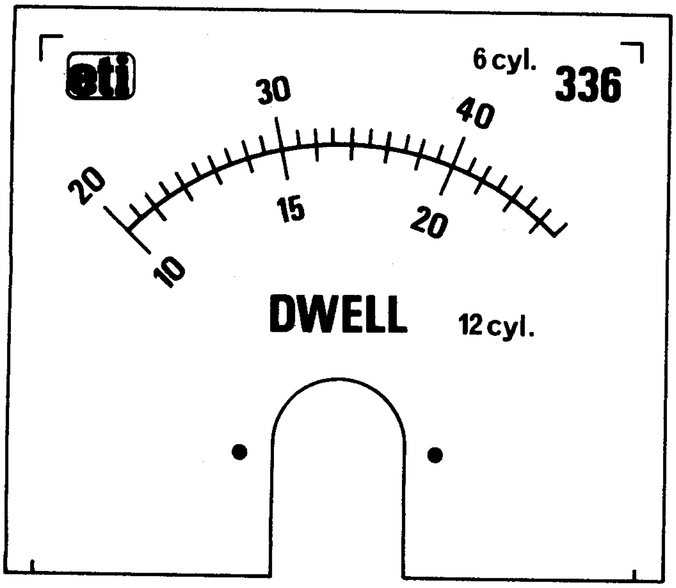
Artwork. Full-size reproduction of the printed circuit board, copper side.

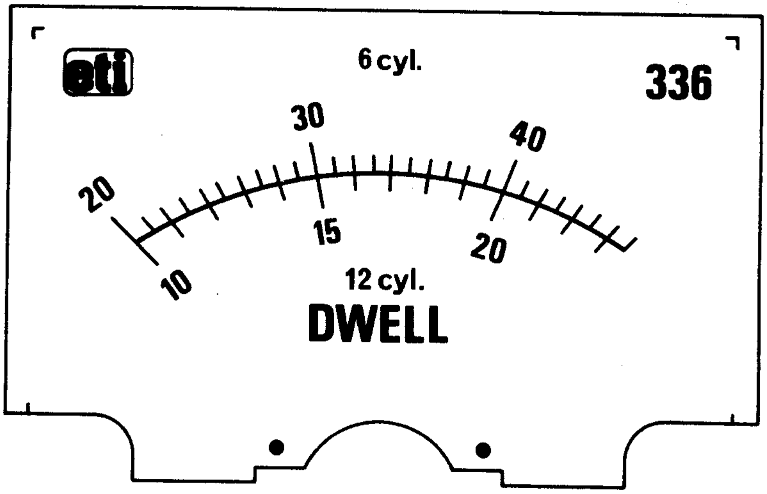


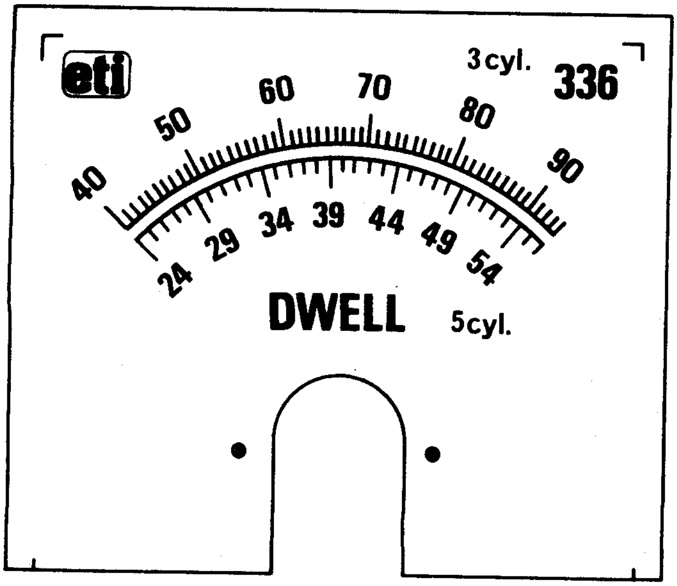
Meter scales. Full-size reproductions of scales for University TD-86 and Minipa MU-65 meters.

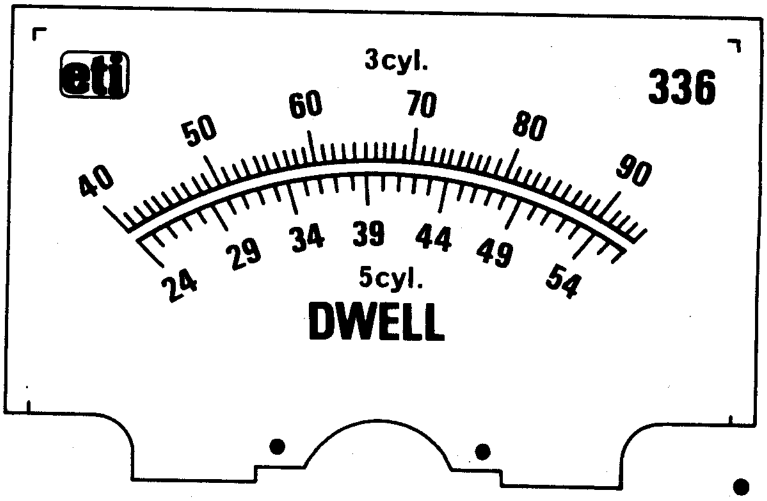












RS232-to-Centronics interface

Geoff Nicholls

Most microcomputers worth owning have an 'RS232' connector, or port, through which serial communications (input/output) is conducted. It is a convention that, for listing on a printer, the BASIC LLIST or LPRINT command assumes a printer is connected to the RS232 port. Problem is, serial interface printers are more expensive than parallel 'Centronics' interface printers. Save some money, build this interface.

WHILE I designed and constructed this project to drive an Admate or TI 850 80-column dot-matrix printer from the lab. Microbee, it is 'universal' enough to suit any application requiring an interface between an RS232C port and a Centronics interface.

Printers with a parallel, or 'Centronics', interface are around $80 to $150 cheaper than with a serial, or RS232C, interface. However, the 'default' printer output on most microcomputers is via the serial interface and a serial interface printer is assumed when LLISTing or LPRINTing from BASIC. This project can be constructed for considerably less than the difference between the cost of a printer with a serial or a parallel interface.

Features

The project simply plugs directly between the computer's RS232C socket and the printer's Centronics connector. It is powered from the +12 V line on the RS232C interface. It is preset to operate at a speed of 1200 baud, but provision has been made for selectable baud rates of 300, 600, 2400 and 4800 (depending on choice of one IC), in addition to that. The data format is also preset, to eight data bits one stop bit/even parity, but other formats can be selected. Tracks etched on the pc board preset the speed and data format, but provision has been made to use either links or DIL switches.

The interface is built around a single supply rail UART ('universal asynchronous, receiver-transmitter) from General Instruments, the AY-3-1015D. This chip pretty well does the whole job, even supplying the acknowledge signal (handshake) for the RS232C port. A 4.9152 MHz crystal is divided down to provide baud rate clock outputs. Either of two IC types can be used here — a 4020B or a 4040B. The 4040B provides only the lower three baud rates (300, 600 & 1200) while the 4020B provides the full complement. However, whichever type is used, it must be capable of running at 5 MHz on a 5 V supply. The minimum speed spec. for Philips and Fairchild devices equals this, but it is lower for National Semiconductor devices — though some chips may run at this speed.

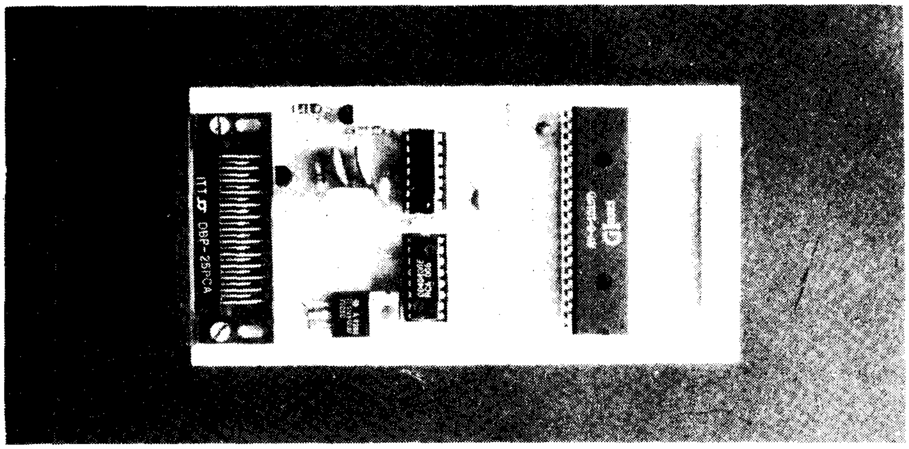
Construction

Assembling the project is quite straightforward. However, there are a few points to watch. Firstly, whether you're using a ready-made pc board or have etched your own, check that all the tracks are intact and that there are no bridges, particularly where tracks run between IC pins. Also see that all the holes are drilled correctly. ▶

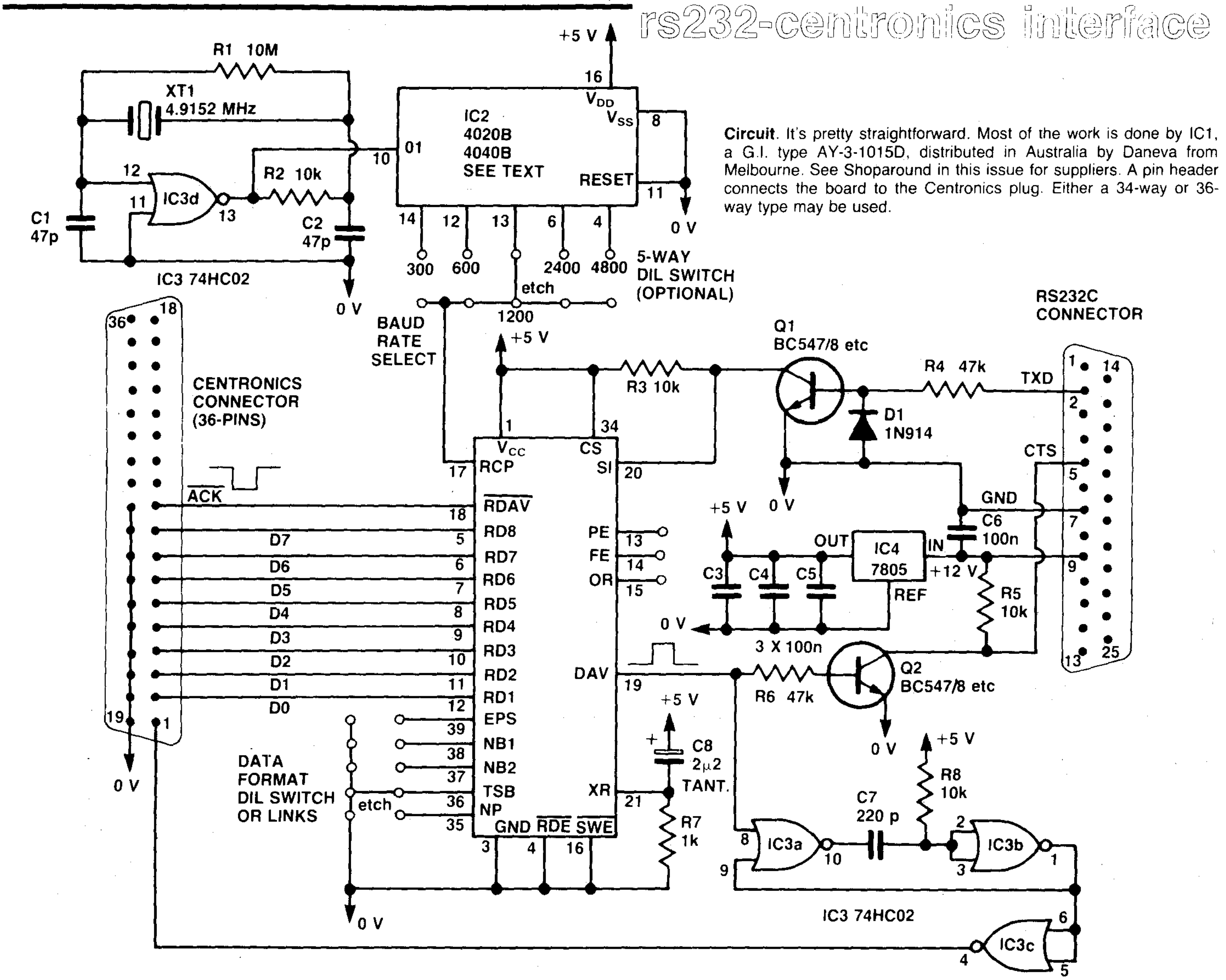
HOW IT WORKS ETI-675

Most of the circuitry in the interface is inside IC1, a universal asynchronous receiver/transmitter, or UART. I have only utilised the receiver section, hence the large number of unused pins. Serial data enters the UART on pin 20 after being inverted and level shifted by Q1 to convert from RS232 voltages to TTL levels. When a complete word has been received the Data Available line (DAV) goes high, indicating that the word is ready to be read out. The DAV low-to-high transition triggers the monostable made from IC3 a, b, c. This generates the Data Strobe signal for the Centronics cable. The DAV signal also drives the Clear To Send (CTS) line on the RS232C side via inverting buffer Q2. This inhibits any further characters from the sending device (i.e: Microbee) until the printer has read the last one sent. When the printer is ready for another character it momentarily lowers the ACKnowledge line on the Centronics cable, which resets the DAV line via the UART input RDAV. This returns CTS to the high voltage and we are back where we started, ready to receive a new character.

The baud rate clock comprises IC3d, a standard crystal oscillator using a high speed CMOS gate, and IC2, a multistage divider. The divided outputs are brought to a



Plug in and go. There's not much to this project. The prototype here is configured to plug straight into a Microbee, but the project is suitable for any micro with an RS232C port.



Circuit. It's pretty straightforward. Most of the work is done by IC1, a G.I. type AY-3-1015D, distributed in Australia by Daneva from Melbourne. See Shoparound in this issue for suppliers. A pin header connects the board to the Centronics plug. Either a 34-way or 36-way type may be used.

pad array, which can be used with a 5-position DIL switch to change rates if you wish. The PC board is etched to only use 1200 baud, so that Microbee users need not change anything.

Either a 4020B or 4040B can be used for IC2, but the highest two baud rates will be different (1200 baud is unaffected). The overlay shows the rates for a 4020B i.e: 300, 600, 1200, 2400 and 4800 baud. If a 4040 is used then the lowest three rates will be the same but extra links will have to run to get 2400 and 4800 baud, owing to the different pinouts.

IC2 must be able to run with a 4.9 MHz clock at 5 V, which is slightly faster than the typical spec. for National devices, but is the minimum spec. for Fairchild or Philips (HEF4020B, HEF4040B). The symptom of a slow device is that the first stage divides by three instead of two, so look at pin 9 with a counter to make sure all is well.

The CR network of C8 and R7 reset the UART on power-up while IC4 and associated components develop the +5 V rail from the RS232C's positive supply. The pads near pins 35-39 of the UART set up the parity and bit length of the serial conversion, they are preset by board tracks to suit the Microbee.

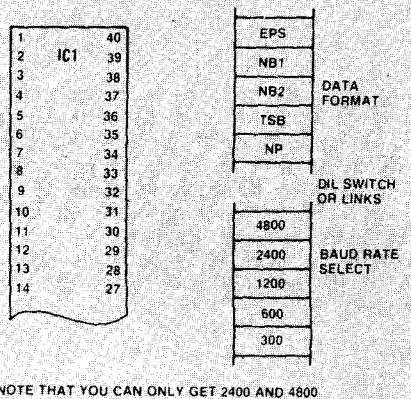
OPTIONAL DIP SWITCHES

The PC board has been laid out to allow the option of fitting two 5-way DIL switch banks, between the UART and ICs 2 and 3. This allows the selection of different baud rates, parity and stop bits. The PC board comes with tracks etched to set eight data bits, one stop bit, no parity bit and 1200 baud. These suit most uses, but if you want to run some other combination then you will have to cut the two tracks and install wire links or DIL switches. The signal definitions are as per the diagram here and Table 1.

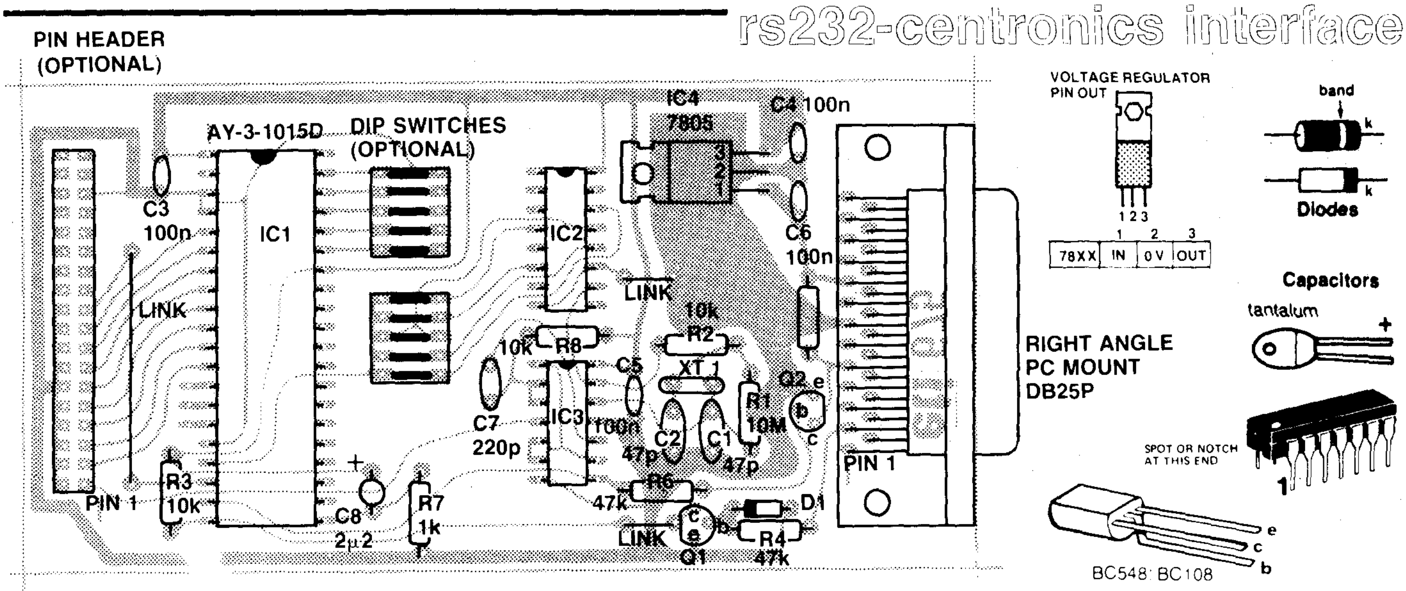
TABLE 1

SIGNAL	FUNCTION		
EPS	ON — ODD PARITY	OFF — EVEN PARITY	
NB1, NB2	NUMBER OF BITS PER CHARACTER		
	NB2	NB1	BITS
	ON	ON	5
	ON	OFF	6
	OFF	ON	7
	OFF	OFF	8
TSB	ON — 1 STOP BIT	OFF — 2 STOP BITS	
NP	ON — NO PARITY	OFF — PARITY EXPECTED	

Only one switch in the baud rate bank may be on at one time, otherwise improper operation will occur.



NOTE THAT YOU CAN ONLY GET 2400 AND 4800 BAUD WHEN USING THE 4020B FOR IC2



PARTS LIST — ETI-675

Resistors	all ¼W, 5%
R1	10M (10% OK)
R2, 3, 5, 8	10k
R4, R6	47k
R7	1k
Capacitors	
C1, C2	47p NPO ceramic
C3, 4, 5, 6	100n 'bluechip' ceramic
C7	220p ceramic
C8	2μ2/6 V tantalum
Semiconductors	
IC1	AY-3-1015D (G.I.) or exact equiv.
IC2	4020B or 4040B (must run at 4.9 MHz on 5 V supply)*
IC3	74HC02
Q1, Q2	BC547, BC548 etc.
D1	1N914
Miscellaneous	
XT1	4.9152 MHz crystal, HC18/U

ETI-674 pc board; right angle pc mount DB25 plug; 34-way pin header (0.1 x 0.1") — optional; 34-way female IDC plug (optional); IDC Centronics plug (if required); 34-way ribbon cable; two 5-way DIL switches (optional); etc.

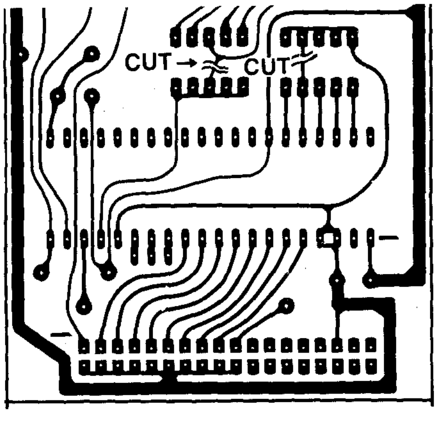
Price estimate: $28-$58

*Philips HEF4020B/HEF4040B and Fairchild 4020B/4040B known to work.

Solder all the resistors and capacitors in place first. Make sure you get the tantalum capacitor (C8) the right way round. Next solder D1 in place, making sure you get it the right way round, too. Follow with the two transistors, Q1 and Q2.

Solder the three links in place next, followed by the three IC sockets and the crystal. The three-terminal regulator (IC4) can be soldered in now. Note that a heatsink is not required for it. If you are using DIL switches for baud rate and data selection, these should be soldered in place next.

Last of all, solder the 34-pin header strip and DB25P right angle connector in place. The latter should be bolted to the board firmly before soldering so that no stress is placed on the solder joints. Insert the ICs now. The UART is an NMOS device, while the other two are CMOS. Take the usual precautions against static damage.



A cut above. To obtain other baud rates and data formats, the two tracks marked above must be cut. Links or DIL switches can be used to select the required configuration.

Make up interconnecting cables to suit your individual requirements (see next section). If you're using a Centronics plug, I strongly recommend you use an insulation displacement type as the solder pin type is much harder to assemble, with a chance of errors and poor connections.

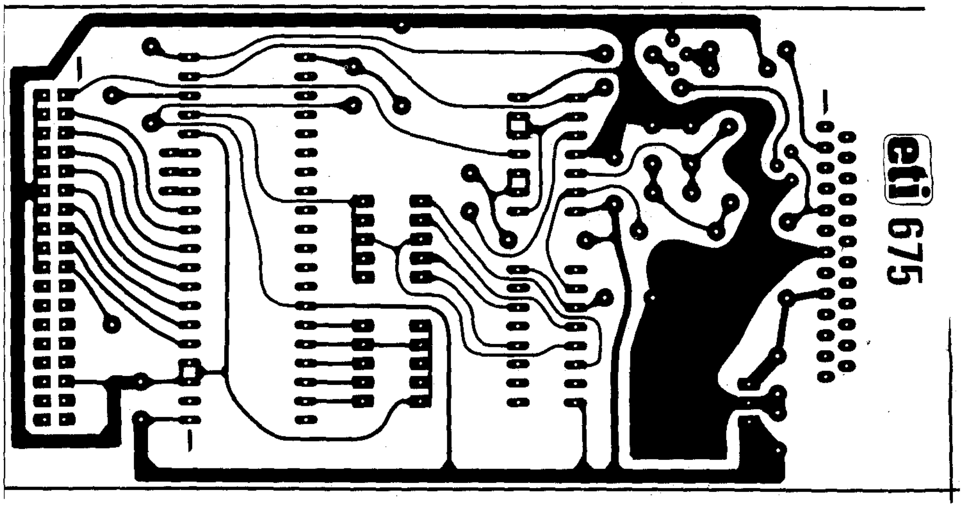
Mounting

Actual mounting details are left up to you, as requirements will vary widely. The board can be mounted inside your printer, in which case the DP25P plug and 34-pin header may be dispensed with and the board wired-in directly. Alternatively, the board may be mounted inside a zippy box, or other suitable case, and cables wired to it with suitable connectors on the end. Or, if you have a Microbee, you can do as I did and plug it straight in to the DB25 socket on the rear of the cabinet and let it hang out the back. A couple of 'feet' might be useful, though. These could consist of two standoff pillars with rubber grommets attached, bolted to the end of the board either side of the 34-pin header. The overall price of the project depends on the connectors and case used — or not used.

Using it

With a Microbee, just plug it in and go! With other micros, setting the baud rate and data format is simply a matter of cutting the two tracks (as indicated in the diagram here) and either installing links or DIP switches and linking the appropriate outputs across as per Table 1.

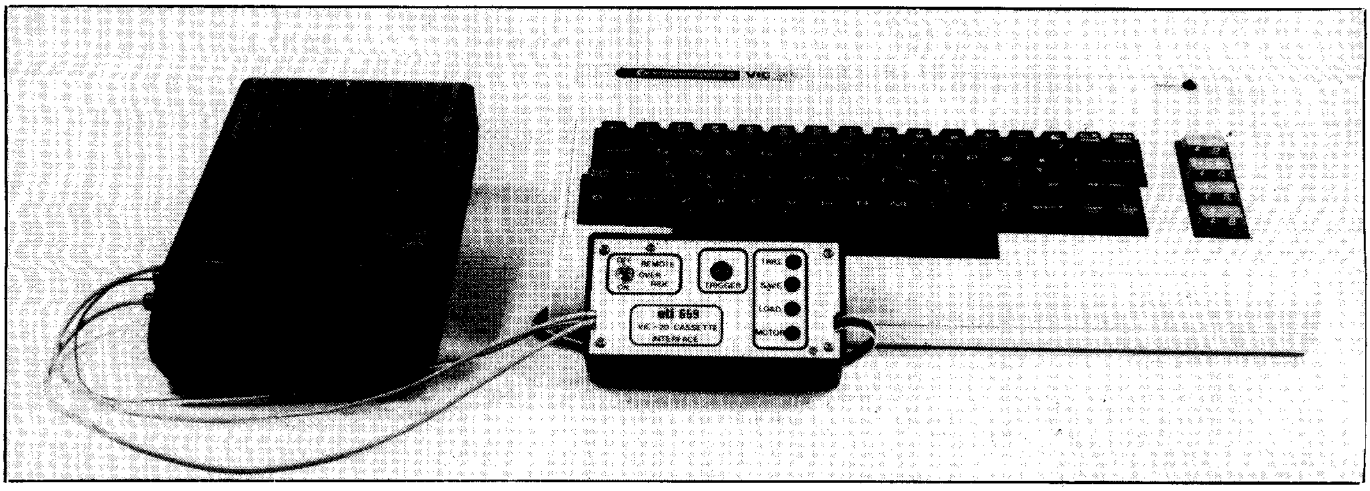
Happy LLISTing! ●



Board artwork. Full-size reproduction of the pc board. ▶

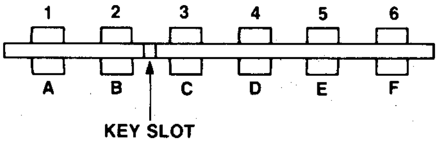
A VIC-20 audio cassette interface

Robert Irwin



This project, developed from an idea submitted by a reader, Paul Wadeson, allows the use of an ordinary, cheap, audio cassette player to load and save programs on the popular VIC-20 home computer.

THIS SIMPLE PROJECT allows all you impoverished VIC-20 owners, who are not in possession of the special VIC-20 Datacassette cassette player, to use your old, cheap, portable audio cassette player for storage and loading of files. Just about any audio cassette player can be used and the interface will supply all the necessary signals to the VIC-20 cassette interface port. Also, if you're lucky enough to have a cassette player with a remote control jack, then the interface will allow automatic stopping and starting of the cassette motor.



Pin	Type
A-1	ground
B-2	+5 V
C-3	cassette motor
D-4	cassette read
E-5	cassette write
F-6	cassette switch

VIC-20 CASSETTE CONNECTOR LOOKING INTO THE BACK OF THE VIC-20

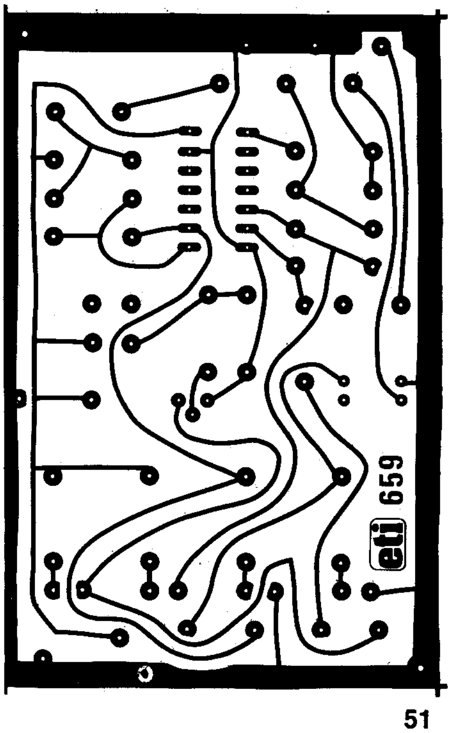
Design details

The cassette interface port on the VIC-20 is a 6-pin, double sided edge connector. Six signals are derived from this connector. These are +5 V, GROUND, CASSETTE MOTOR, CASSETTE READ, CASSETTE WRITE and CASSETTE SWITCH.

CASSETTE READ and CASSETTE WRITE are the data lines for loading and saving respectively. CASSETTE MOTOR is intended to turn the cassette on or off at the appropriate places during a save or load and CASSETTE SWITCH is an input signal which tells the computer when the play and record buttons are pressed on.

Most standard portable audio cassette players are set up with an earphone jack, a microphone jack and a remote jack. The interface uses the earphone jack for the READ data line and the microphone jack for the WRITE data line. The remote jack is controlled via a relay by the CASSETTE MOTOR signal and is used to turn the player on or off. The CASSETTE SWITCH signal is required to be low to indicate that the play button on the cassette player has been pressed. This is achieved with a manual pushbutton mounted on the interface. The circuit is adapted from the popular ETI-660 Leaner's Microcomputer (1981) which proved to be reliable and relatively easy to use and is known to work with a wide variety of audio cassette players. ▶

Printed circuit. Full-size artwork.



Construction

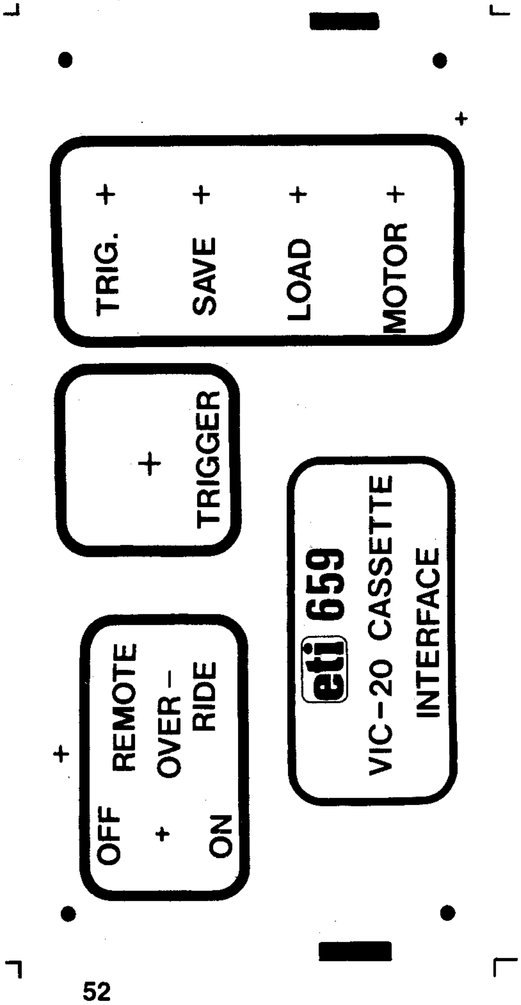
Construction is very simple as all of the components, with the exception of the manual override switch, are mounted on the pc board. Begin by carefully examining the pc board for any faults. Look for holes not drilled or incorrectly drilled and any small copper 'bridges' between closely-spaced tracks as well as for broken tracks. If everything is OK then solder the resistors and capacitors in place as per the overlay diagram. The relay and pushbutton can be mounted next followed by the transistor and IC. Finally, mount the four LEDs. These should be mounted so that the bottom of each LED stands about 7 mm from the face of the pc board. Do not cut off the excess lead on the LEDs yet in case the height needs to be adjusted later.

The prototype was housed in a medium (41x68x130 mm) zippy box. This was found to be an ideal size to house the interface. The aluminium lid should be removed and marked out for drilling using the front panel artwork as a template. Carefully line it up on the front panel and prick through the artwork at the hole centres using a scriber or compass point. Before drilling, just give a quick check to see that the pushbutton and LEDs line up with the marked centres. The hole for the pushbutton should be large enough to allow good clearance to enable the button to move in and out freely without snagging. A 7x12 mm indent should be cut in both ends of the front panel to allow for the entry of the cassette and VIC-20 connection cables.

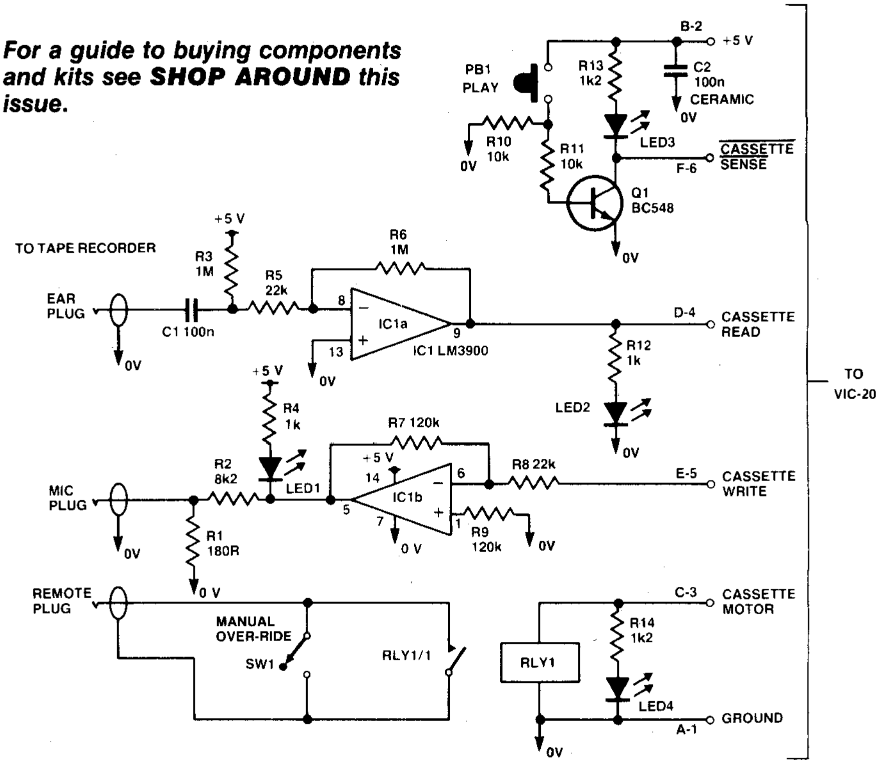
Once the front panel has been drilled a trial assembly should be done to ensure that the height of the LEDs is correct and that the pushbutton moves freely. If all is well then the Scotchcal front panel label can now be attached. Peel the backing off one edge and line this edge up with the appropriate edge of the lid. Carefully smooth the edge down until it has stuck and then pull off the remainder of the backing and smooth the rest of the label down. Once the label is in place, smooth out any remaining bubbles working from the centre out. The holes can now be trimmed out using a sharp knife or scalpel.

Before mounting the pc board to the front panel, attach suitable lengths of shielded cable and ribbon cable to the pc board as shown in the wiring diagram. The cassette lines should be terminated with appropriate plugs (usually 3.5 mm plugs for the earphone and mic sockets and a 2.5 mm plug for the remote socket).

Front panel. Full-size artwork.



For a guide to buying components and kits see SHOP AROUND this issue.



HOW IT WORKS — ETI-659

The interface is really four independent circuits on the one board. Let's start with the CASSETTE MOTOR circuitry.

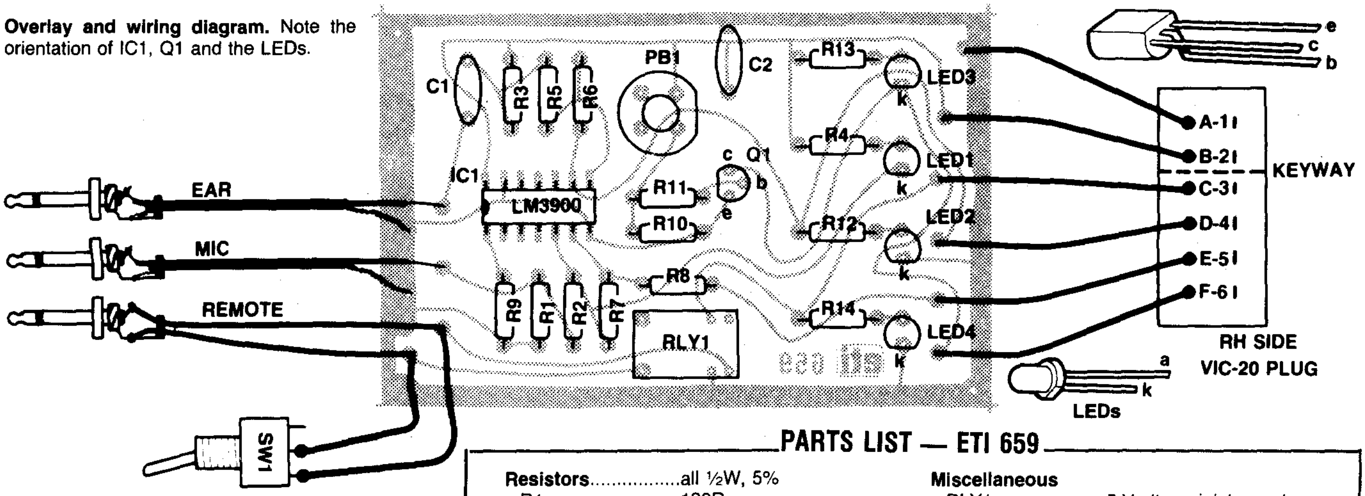
Pin C-3 on the VIC-20 cassette interface port provides a 6 V signal when the motor is to be switched on. In the interface this signal is applied to the coil of a 5 V ultra-miniature relay. This then pulls in the normally open contacts which are connected to the remote jack of the tape recorder. This switches the recorder motor on. Switch SW1 is connected in parallel with the contacts and is used to manually switch the recorder motor on. Resistor R14 and LED4 provide visual indication that the contacts are closed.

The circuitry associated with Q1 provides the cassette SWITCH signal to the VIC-20. When pushbutton PB1 is pressed, base drive is applied to Q1 via R11. This turns the transistor full on and allows current to flow through R13 and LED1. The collector voltage of Q1 drops to a few millivolts. This signals the computer that the cassette is on. When the pushbutton is released the transistor is turned off and the collector voltage rises to about 5 V. Capacitor C2 is used to filter the 5 V supply from the VIC-20.

IC1 is an LM 3900 Quad Norton op-amp which can be run from the single +6 V supply. The LOAD circuitry uses on op-amp (IC1a) as an inverting amplifier stage. The gain of this stage is set to 45 by R6 and R5 and acts to 'square-up' the signal from the tape which is fed in via a coupling capacitor, C1. With a suitable level signal from the tape recorder, the output of the op-amp (pin 9) will drive from 0 V to +5 V and supply the signal to the CASSETTE READ input of the computer. This signal is also used to drive LED2 which acts as a visual indication that data is being loaded.

The CASSETTE WRITE pin from the computer drives another op-amp in the LM3900 package. This op-amp is configured as an inverting buffer with a gain of five set by R7 and R8. The output is then attenuated by a factor of 50, by R2 and R1, to a level suitable for recording. Varying R2 will vary the amplitude of the signal to the microphone input and can thus be changed to suit the recorder in use, although the given value should be suitable in most cases. LED1 works in a similar manner to LED2 and indicates that data is being transferred to the cassette.

Overlay and wiring diagram. Note the orientation of IC1, Q1 and the LEDs.



PARTS LIST — ETI 659

Resistors	all ½W, 5%
R1	180R
R2	8k2
R3, R6	1M
R4, R12	1k
R5, R8	22k
R7, R9	120k
R10, R11	10k
R13, R14	1k2
Capacitors	
C1, C2	100n ceramic
Semiconductors	
IC1	LM3900
Q1	BC548, BC108 etc.
LED1, 2, 3, 4	5 mm red LED, TIL220R etc.

Miscellaneous	
RLY1	5 V ultra-miniature relay, pc board mount (e.g: Fujitsu FRL-211/D005-M).
SW1	SPDT miniature toggle switch.
PB1	Momentary action pushbutton, pc mounting (e.g: Altronics S1095/6/7/8/9).

ETI-659 pc board; two 3.5 mm audio jacks; one 2.5 mm audio jack; 6- or 10-pin 0.156" pitch edge connector; 200 mm of 6-way ribbon cable; one metre of shielded cable; two 12 mm spacers; jiffy box (130x68x40 mm); nuts, bolts and hookup wire; Scotchcal label.

Price estimate: $18-$20

To terminate the ribbon cable a 6-pin, 0.156" pitch edge connector is required. These seem fairly scarce, so on the prototype, I used a 10-pin connector and cut it down to size. It may be possible to get the "proper" connector from Commodore or a Commodore dealer (good luck!). Take care when wiring this plug to get the pin connections correct. The pinout for the VIC-20 cassette interface is given in the accompanying diagram.

The next step is to mount the remote override switch onto the front panel. This should then be connected to the PC board with about 50 mm of light gauge hookup wire. The pc board can now be mounted on to the back of the lid using 12 mm spacers. Make sure that the pushbutton moves freely and that the LEDs are the correct height to just poke through the holes by a couple of millimetres. If desired, LED mounting rings can be pushed into the holes first to hold the LEDs. Once the pc board is mounted the excess lead on the LEDs can be trimmed off. To complete construction, mount the lid assembly into the box ensuring that the connection cables fit neatly into the indents that you cut out of the lid.

Testing and using it

Before connecting the interface make sure that the VIC-20 is turned off. Plug the 6-pin edge connector into the cassette interface port making sure that it is the right way round, then turn on the VIC-20. A normal power-up message should be displayed. If a normal power up does not occur then switch the machine off immediately and check all wiring and connections on the interface. Once a normal power-up has been achieved there should be no LEDs lit on the interface unit. Check that when the pushbutton is pressed the TRIG and MOTOR LEDs are lit. If one or both LEDs stays off when the button is pressed then check the orientation of the LEDs and also of the transistor. You should also hear a click as the relay trips when the pushbutton is pressed.

If the switching is working correctly then connect up a tape recorder to the interface and insert a blank tape. If the remote plug is being used then, with the manual override in the off position, the cassette motor should be disabled. To check this press the PLAY button on the cassette. The motor should not turn on. If the trigger button is now pressed the motor should turn on until the pushbutton is released. To gain manual control for rewinding or cueing just turn the remote override switch to on.

When loading or saving just type in the appropriate command. The VIC-20 should respond with a "PRESS PLAY ON TAPE" or "PRESS PLAY AND RECORD ON TAPE" prompt. You then just press the appropriate buttons on the cassette recorder and then the TRIGGER button on the interface. The cassette will then start and the MOTOR LED indicator should stay on.

During a SAVE or LOAD operation the appropriate LED on the interface will glow when information is being transferred. If these LEDs do not glow then this indicates that no information is getting through. This could be due to too low a volume setting on the cassette recorder.

As with most cassette storage systems it will be necessary to experiment with the playback volume in order to get reliable loading. Too high or too low a volume will result in a bad load and a LOAD ERROR message will appear on the screen. From experience I have found that if the playback volume is too high then, during a LOAD, the computer will frequently stop the tape and display the PRESS PLAY ON CASSETTE message. If the volume is too low then the computer will not read anything and will just keep searching through the tape.

If a CRO is handy, then the level can be set by examining the signal at the D-4 output of the interface during a load. Before the program information is accessed there will be a stable tone generated. The volume should be set so that this signal just begins to clip. If no CRO is available then just set the volume to about half way and do some trial and error adjusting from there.

Happy loading! ●

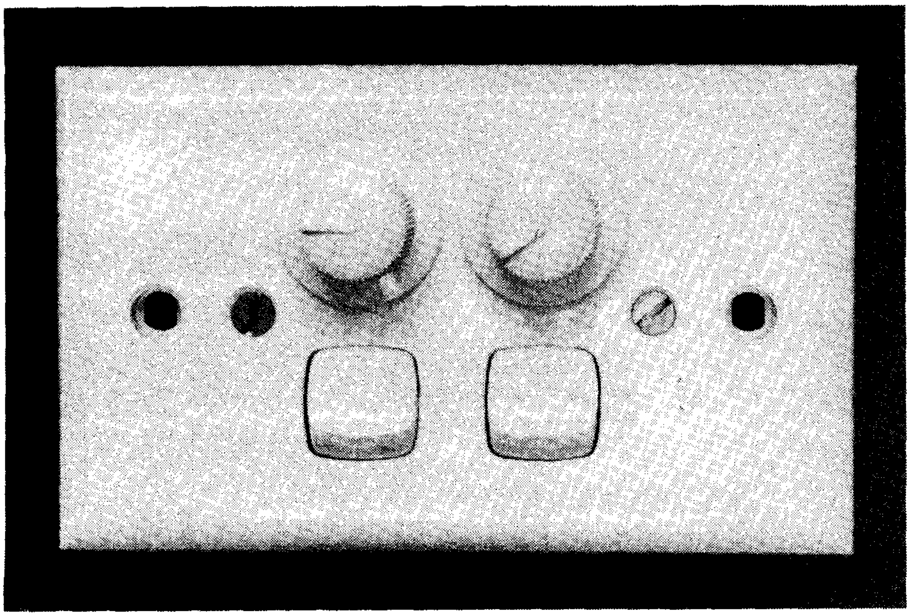
Project 1522

Control up to four room lights over a twin-wire cable

Ian Thomas

Part 1

It is probably a not-uncommon problem to want to replace the single ceiling light in a room with a more exotic dimmable arrangement only to find that the twin-wire switch cable is concreted in, or otherwise hard to get at without spoiling the room decoration. This project allows you to control up to four room lights — two dimmable and two switched — over the existing twin-wire cable. No need to spoil the wall and ruin the room decor.



The controls. I modified a standard, commonly available, HPM light fitting (made in Australia) to take the controls. This provided a neat and convenient solution, the switches and dimmer pots snap into the panel, the encoder pc board mounts behind them. The end result is only distinguishable from an 'ordinary' light fitting by the two pc board mounting screws visible here (which should be earthed or covered). If the pc mountings are epoxied in place — who'd know the difference?

IT IS PROBABLY a not uncommon problem to want to replace the single overhead light fitting with a more exotic dimmable arrangement only to find that the control wires to the switch are *concreted in*. Also, in keeping with Murphy's Law, the walls have only been re-papered a year or so ago and the wallpaper is now totally unavailable and to string more wires to the switch would involve a major redecoration of the whole room, so the idea is scrapped.

This project is intended to solve such problems by replacing the single wall switch with the required multiple switch-control pot combination and a very compact printed circuit board. A matching electronics box in the ceiling feeds power to the control board and also recovers the control information to operate triacs to drive the multiple lights.

It was considered essential that the replaced wall controls look exactly like normal 'bought' controls and avoid that 'home made' look so, normal, purchased, wall fittings were used for the controller. The unit in the ceiling merely had to work reliably and could be any size or shape at all.

The design

The first problem to be dealt with in the design was how many controls and what type were wanted. Also, it had to be decided how to multiplex the switch/control pot information onto the single wire pair available. A survey of the many types of controller integrated circuits available (what we were trying to do is not dissimilar to the remote control of a TV or VCR) showed that while there were dozens (literally!) manufactured, precisely none (zip! zero! zilch!) were to be had in Australia unless you wanted to buy 1000 or so.

The only ray of light to be found was from National Semiconductor, and a perfectly satisfactory ray it turned out to be too. National make the LM1871 Radio Control Encoder/Transmitter and its companion LM1872 Radio Control Receiver/Decoder, which are intended to be used as remote controllers for toy cars or model aeroplanes. They provide, in their simplest configuration, two linear analogue control channels plus two separate on-off channels. The encoder/transmitter also contains a moderate power high-f_T transistor to be used as an RF transmitter and the receiver/decoder has all the circuitry to construct a (simple) RF receiver so, as I could actually go out and buy some over the counter (good marketing National!) this integrated circuit pair seemed to be the way to go. They would give two completely linear, dimmable lights plus two simple on-off lights which should cover most rooms adequately.

The LM1871/LM1872 integrated circuits operate on a rather peculiar combination of pulse-width modulation plus (once again in their simplest configuration) pulse counting to transmit the analogue and digital information. The receiver/decoder half of the pair contains no memory so the encoder/transmitter must send the information continuously to keep the system 'alive'.

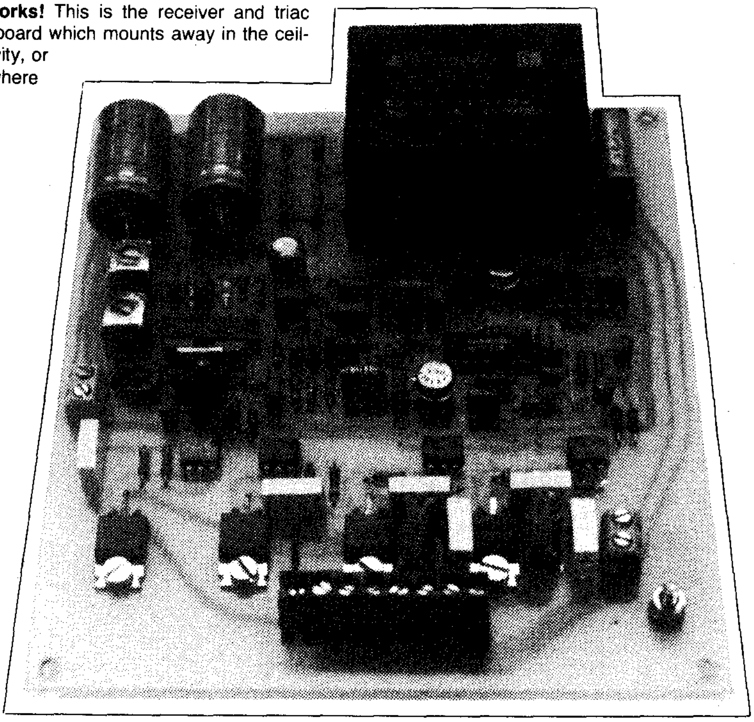
The encoder section of the LM1871 generates a series of up to six pulses in each data frame with each pulse separated by a fixed off time. At the end of the up-to-six pulses a much longer synchronisation pulse is sent so the receiver/decoder can lock on correctly. The first two pulses in each data frame are of variable width to convey the analogue information of the two channels and the other, up-to-four, fixed width pulses give the status of the two on-off switches. Figure 1 shows a typical encoder output and indicates how the width of the first two pulses gives the analogue data.

As Figure 1 shows, the analogue information is contained in pulses repeated at the frame rate whose width varies. The values recommended by National give a frame rate of 50 Hz. However, as the analogue information derived from this repetition rate data is to be used to control triacs running from 50 Hz mains the two similar frequencies would be sure to give rise to all sorts of unwanted slow beat effects (you would be amazed how sensitive the eye is to slow beats in, say, light intensity). For this reason I opted to have a frame rate of 75 Hz so any beats would be at 25 Hz and thus unnoticeable.

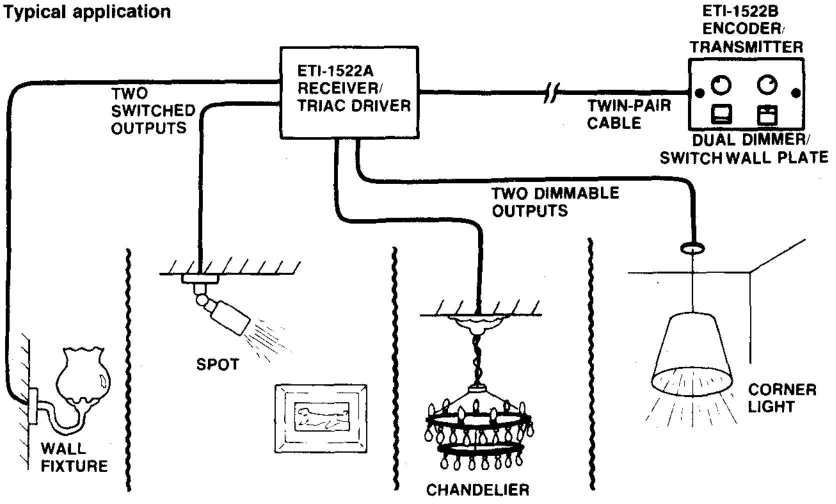
Also, the National design data is based on bandwidth restrictions and no such restraints exist for us. I also opted to shorten the fixed off time between all pulses to 0.4 ms from the National-recommended 0.5. The analogue channel limits were left the same as in the recommendations at 1 ms minimum and 2 ms maximum. The digital information pulses were left at 0.5 ms to finish defining all the times in the frame sent from the encoder.

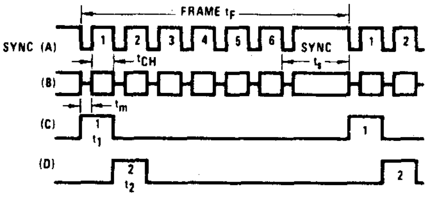
The LM1871 is intended to be used as a very low power 27 MHz or 46 MHz (or, by straining and a bit of extra circuitry 72 MHz) radio transmitter. This seemed like a good idea except that I had no desire to further crud up the ether with lighting control information. Instead, I chose to use the wires carrying power to the controller to carry switched low frequency RF data in the ▶

The works! This is the receiver and triac driver board which mounts away in the ceiling cavity, or somewhere else.



Typical application

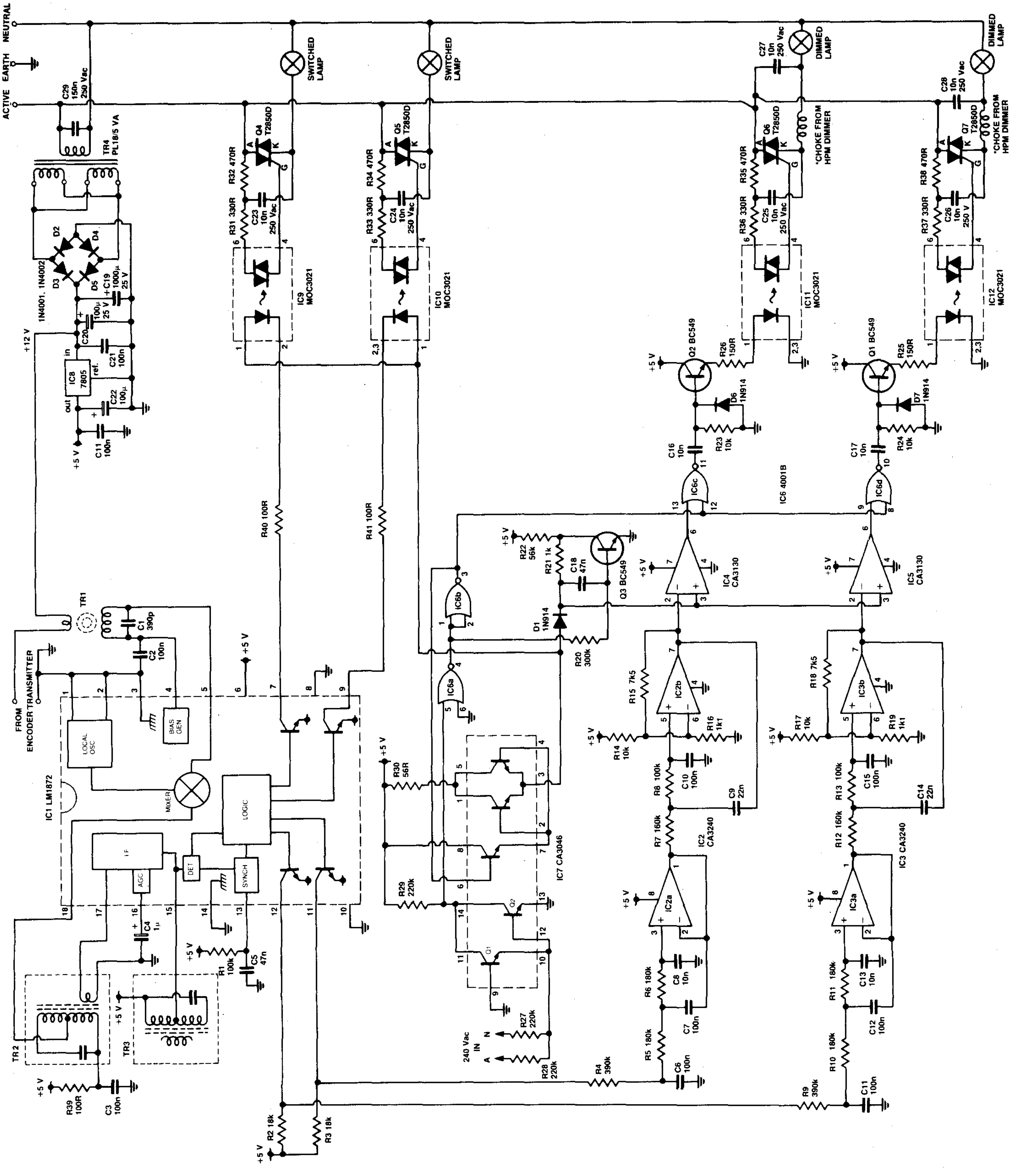




(A) Encoder Output (Pin 13)
(B) Transmitted RF Carrier Envelope
(C) Typical Receiver Channel 1 Output
(D) Typical Receiver Channel 2 Output

Figure 1.
Typical encoder output waveform. The width of the first two pulses gives the analogue data.

Circuit of the receiver and triac driver (ETI-1522A)



HOW IT WORKS — ETI-1522

The light controller can be divided into two major sections; the transmitter and the receiver and the receiver itself can be divided into several sections which are: the RF receiver, analogue filtering, mains synchronisation and triac drive. First, consider the transmitter.

The transmitter sends its information as to potentiometer position and switch status by sending a series of between three and six data pulses followed by a much longer pulse to synchronise the system (see Figure 1). All the pulses are separated by an off period of exactly the same time. The first two pulses are individually pulse-width modulated to encode the two analogue channels and the next one-to-four pulses contain the switches, encoded by a simple counting system. As the width of the first two pulses and also the number of subsequent pulses can vary, the actual time taken for data transmission varies as the input controls are varied. However, the LM1871 allows for this by varying the length of the synchronising pulse so the length of every data frame is the same.

While it is interesting to go into details of the internal operation of the LM1871 the essential part is to understand how the external components affect the operation of the integrated circuit. The IC consists of several separate RC timing circuits and some combining logic, together with voltage reference generators to give both stable timing and stable RF output level. Overall data frame timing is set by R8 and C10 and this time constant sets the 75 Hz data rate for the system. The time between each individual pulse of the data and the duration of each data pulse is set by capacitor C11, together with different resistors for the inter-pulse time and the actual pulse durations.

When the LM1871 is measuring the time between the pulses it is charging C11 from $0.33\ V_{ref}$ to $0.67\ V_{ref}$ by switching in R1. When the LM1871 determines an actual pulse it discharges C11 through the resistor associated with that pulse. For example, when it sets the length of the first pulse in the data frame it switches in the resistance connected to pin 3, which is R7 and RV2. Thus, R7 sets the minimum pulse width of the first analogue channel and RV2 varies the pulse width from that minimum. The same cycle is repeated for the second analogue channel; charging C11 through R1 and then selecting the second discharge resistance, R6 and RV1.

If desired, four more analogue pulse-width modulated channels can be generated by connecting four more variable resistors to pins 1, 18, 17 and 16 but we don't want six analogue channels and also, the LM1871 contains extra circuitry to convert these potential extra channels to two digital channels and at the same time make the receiver much simpler. If pins 1, 18, 17 and 16 are all connected together (as they are here) then for pulses three to six, the same resistor will be used and the last four pulses will have the same length.

Internal logic exists in the LM1871 to operate on information provided on pins 5 and 6 and vary the number of pulses that are sent according to that information. For example, if both pins 5 and 6 are left open (the IC has internal pullup resistors) then only one fixed duration pulse is sent after the two analogue pulses and the rest of the frame time is made up with the synchronising pulse. If both pins 5 and 6 are shorted to ground then a further four fixed duration pulses are sent and the synchronising pulse is proportionally shorter. This is clearly illustrated in Figure 2.

This takes care of the encoding and timing but leaves the problem of the actual transmission. For this purpose the LM1871 provides a single transistor with its emitter internally connected to ground (which removes a few design options but I think they ran out of pins!). As I wanted an oscillator whose frequency was stable but didn't want to spend money on a crystal I chose to use a ceramic resonator as the major frequency selective element. These resonators behave very much like crystals except that they are not quite as accurate or stable and seem to have a whole lot more spurious resonances. In order to control the spurii it is necessary to have the oscillating amplifier selective by itself so that where the spurii occur there is **low loop gain.**

In the circuit chosen, the collector of the oscillator drives a tuned circuit and the power supply and ac earth is connected to a tap almost at the other end of the coil. Thus, the other end of the resonant circuit has a voltage in opposite phase to the collector and of much lower amplitude, suitable to drive the base. The signal to the base is divided down through C6 and C8, together with the ceramic resonator. Thus, the base drive is heavily attenuated for all frequencies except the resonant frequency of the ceramic resonator which controls the frequency of oscillation.

The output from the oscillator is taken from a secondary winding and one end is tied to ac earth via C5. The other side of the winding has a current limiting (and impedance defining) resistor R3, which connects to the +12 volt supply line. Thus, the oscillator signal is coupled at low level to the transmitter supply. R2, C1 and C2 protect the logic circuitry from interference from the transmitter output.

Capacitors C3 and C7 are used to wave shape the data pulses out of the digital section so the RF spectrum of the transmitter output does not "splatter", but this is principally for radio type applications and not strictly necessary here. They are included more for nicety that necessity.

The receiver and data recovery part of the main controller revolves around the National LM1872 which is the companion IC to the LM1871 transmitter. The receiver section of the LM1872 is designed as a superheterodyne receiver, but for this application all that was necessary was a tuned amplifier at 455 kHz with adequate agc as it is indeterminate what attenuation from the transmitter can be expected. For this reason, the local oscillator section of the LM1872 was disabled by grounding its crystal inputs, pins 1 and 2. This makes the mixer of the LM1872 into a simple amplifier (the local oscillator modulates the emitter current of a differential pair and grounding pins 1 and 2 sets a constant emitter current). Thus, what would normally be the RF input becomes an "IF" port and accepts the input from the line.

The actual input signal is coupled in by TR1, a 20:1 step down transformer. The primary is a single turn and the secondary is 20 turns wound around a Philips 3H1 9 mm toroid. This gives a secondary inductance of about 320 μH which resonates with C1, a 390 pF capacitor, at 455 kHz. Thus, the high input impedance as seen at pin 5 of the LM1872 is transformed down by 20^2 to present a few tens of ohms to the 12 volt supply line at 455 kHz and almost no impedance for other frequencies.

The next two stages in the IC provide more than adequate gain for our needs. TR1 couples into the base of one side of a differential pair and TR2 is connected to the collector of the opposite side. The secondary of TR2 couples via diode biassing to the lower section of a cascode pair which is also part of the agc system. TR3 acts as a simple resonator in the collector of the upper transistor of the cascode pair. This collector also drives the agc system and rf detector. Thus, as the agc system has high gain itself, the RF level seen at pin 15 doesn't vary and it is necessary to monitor the dc agc voltage when tuning the receiver.

Once the detector has recovered a binary signal from the RF data bursts the LM1872 must separate the two analogue channels and, by pulse counting, determine the state of the two transmitter switches. The LM1872, like the LM1871, has one master timer which is used to recover frame rate. This is set by R1 and C5. Whenever the LM1872 sees no incoming RF it resets the timer R1C5 and while a continuous carrier is being received the timer is allowed to exponentially rise (see Figure 3).

If the carrier is present for long enough, such as for a synchronising pulse from the LM1871, then a comparator in the LM1872 fires and its decoding cycle is started. The next ON to OFF transition is read as the start of the first analogue pulse and the next ON-to-OFF transition is the end of the first channel pulse and the start of the second. The third transition terminates the second analogue channel pulse and from then on the LM1872 merely counts ON-to-OFF transitions to determine the status of the transmitter switches.

The two digital outputs from the LM1872 are used to drive the cathodes of two optocouplers directly and the anodes are pulsed on zero crossings of the mains. For the two analogue channels the processing necessary is more complicated. The outputs from the IC are set as open collectors and R2 and R3 act as pullups to 5 V. All the timing from the LM1871 is set so that the two analogue channels have pulse widths of between 1 ms and 2 ms (with an allowance for tolerancing — it is less than one and more than two).

As the 75 Hz frame rate gives a pulse repetition rate of 13.33 ms then the two pulse-width modulated outputs have dc components of between 5(1/13.33) and 5(2/13.33) or approximately between 0.4 and 0.8 volts. Superimposed on this is a very strong signal at 75 Hz, plus harmonics. Therefore, the dc component must be dc-shifted and amplified to give an output of between 0 V and +3 V. The two active filters achieve this and provide an attenuation of about 60 dB for the 75 Hz. They are equiripple group delay filters with a phase ripple of 0.5°, which provide an optimum transient and frequency response for this application (see text).

As the dc output is being used to fire triacs, the dc must be related to mains 50 Hz to be of use. IC7, and principally transistors pins 9-10-11, labelled Q1, and pins 12-13-14, labelled Q2, are used as a mains zero cros- ▶

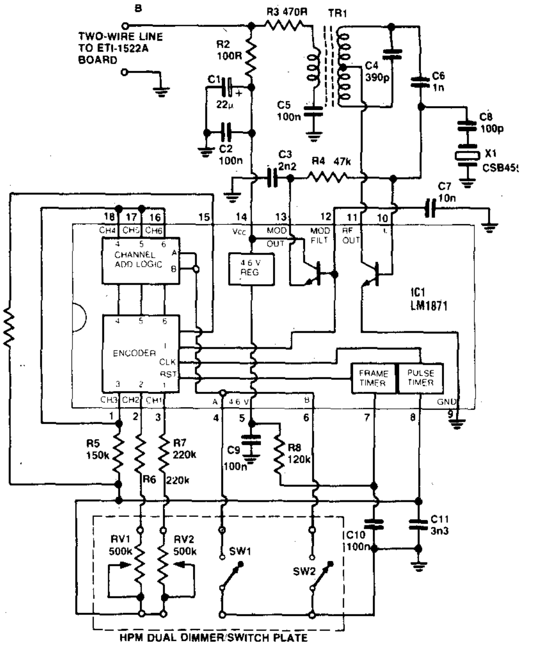
. . . How It Works, continued.

sing detector. The base of Q1 and the emitter of Q2 are both grounded and the emitter of Q1 is connected to the base of Q2 and, via R27 and R28, to the actual 240 volts 50 Hz mains (one of the resistors is connected to the active and the other is connected to neutral so that if active and neutral are reversed, then everything still works). When the mains is at greater than one Vbe above ground Q2 is turned on. Also, when the mains voltage is greater than one Vbe below ground then Q1 is turned on (in fact it must be less than −5 V before Q1 saturates completely). Only for mains voltages between ±0.6 volts are both transistors completely off and their common collectors, pins 11 and 14, at +6 volts. Thus, the two commoned collectors have a positive-going pulse every time the mains voltage passes through zero. This pulse is buffered and cleaned up by two gates in IC6.

The buffered, positive-going pulse is impedance transformed by the rest of the transistors in IC7 acting as a Darlington emitter follower and used to reset a ramp generator formed by Q3 and its associated resistors and capacitors. C18 is forcibly charged to about 2.6 volts through D1 on a mains zero crossing (the other side of C18 is held at 0.7 V by Q3's base). C18 is then charged through R20 and the current is mirrored by collector current through R21. This produces a linear negative-going ramp at the node of C18, D1 and R21. This ramp is applied to the non-inverting inputs of the two analogue channel comparators while the dc signals derived from the filters are applied to the inverting inputs. The two gates of IC6 following the comparators ensure that even when the comparators are always low, which corresponds to lights full on, there is still a pulse on mains zero crossing to fire the triacs. The gate outputs are CR differentiated and buffered, then used to drive the MOC3021 optocoupler input anodes directly.

The four triacs have one terminal connected permanently to the active mains input, the other is connected to the load. This means that when the triacs are off, the driven light fittings are safe. A second, much smaller, triac in the *optocoupler* is used to trigger the main one on for each circuit. A resistor-capacitor-resistor combination protects the optocoupler triacs from excessively high dV/dt and hence accidental triggering from mains transients. The two triacs that are driven from the dimmer controls have simple LC filters in their outputs to suppress radio frequency interference. The on-off triacs have no need for this as they are always fired on zero crossings.

Circuit of the encoder/transmitter.



opposite direction. The coil used to operate the transistor in the IC provided as an oscillator also gave an easy way of injecting the oscillator output onto the line. Oscillator frequency stability was provided by using a **455 kHz IF ceramic resonator (readily available** from Tandy, and others) as part of the feedback.

As the LM1871 provides all the necessary circuitry to modulate and waveshape the oscillator output from the encoder output, a complete and compact controller was easy to construct.

The actual controls feeding the LM1871 were made from modified light fitting controls purchased for the purpose. I chose to use HPM light fittings as they have a neat and convenient arrangement where a panel is purchased with the required number of holes as there are to be controls and then the controls (switches or dimmers) are snapped into the panel.

In order to keep things looking exactly like ordinary light fittings I bought two light dimmers and removed all the works from them except the 500k pots, which are the *dimmer* control elements (see How It Works). The end result can only be destinguished by the two mounting screws for the electronics printed circuit board. In order to save space in the controller all capacitors are the smaller 5 mm pin spacing, 63 V metallised film type which are increasingly becoming an industry standard and are available from many manufacturers.

Once the encoder transmitter had been designed and modelled, the next problem was to design a modified receiver decoder which would recover the 455 kHz bursts and regenerate the analogue and digital information. The LM1872 contains all the circuitry for a complete superheterodyne receiver which was somewhat more than was strictly necessary for this application. The on-chip local oscillator was therefore disabled and only the IF amplifier section used. Two of the IF transformers from a set carried by Dick Smith Electronics (L-0260) were used and gave satisfactory performance.

The 455 kHz was coupled from the power supply line with a toroidal transformer whose output was approximately resonated with C1, a 390pF capacitor. This means that the input impedance of the RF section is accurately transformed down to about 20 ohms to recover the 455 kHz from the line. The agc for normal applications is filtered with a 100 nF capacitor on pin 16. In this application, where there is no variation in input signal level, the filter capacitor can **be increased to 1 μF, or even greater, with** no problems and in fact helps by preventing the agc following the input pulses.

The LM1872 IF and detector sections recover the pulses generated by the LM1871 encoder and pass them onto the decoder section whose operation is shown in Figure 2. It can be seen that the decoder simply counts negative-going edges after the synch pulse to determine the status of the two switches in the LM1871 circuit. The timing diagram also illustrates just how the LM1872 derives timing information from the first two pulses after the synch pulse for the analogue channels.

Figure 3 shows how different numbers of pulses are sent from the LM1871 to convey switch status. As the frame timing in the LM1871 is set by a separate resistor and capacitor from the data RC circuit, as the number of data pulses is reduced the synchronising pulse gets longer so the frame rate remains constant at 75 Hz.

In the decoder circuit used, both the ana**logue and digital outputs were configured** as open-collector transistors (the LM1872 offers a choice of open-collector or open-emitter drivers for the digital outputs). Processing of the digital outputs was no problem and the collectors switched the triac drives directly (see "How It Works").

However, the analogue channels needed a lot of processing before they could be used to operate triac drives. As the whole of the LM1872 had a maximum operating voltage of 7 V the whole of the receiver and triac drive circuitry was operated from a regulated 5 V rail. (I'm sure National had a good reason for the voltage restriction but it escapes me).

When resistors R2 and R3 are connected to the output collectors the resultant output is a pulse-width modulated signal with the pulses swinging between about 40 mV (the transistor V_{ce} sat) and 5 V. This signal has a dc component and a somewhat larger ac signal. In order to recover and amplify the dc, and at the same time remove the ac, several methods were considered but finally the simple and straightforward way was chosen; namely — a low pass filter to preserve and amplify the dc and at the same time provide about 60 dB attenuation of the 75 Hz fundamental (and appropriately more for the higher harmonics of the ac signal).

When it comes to filters there must be about as many different types and class of filter as there are applications; and there are an equally large number of realisations for

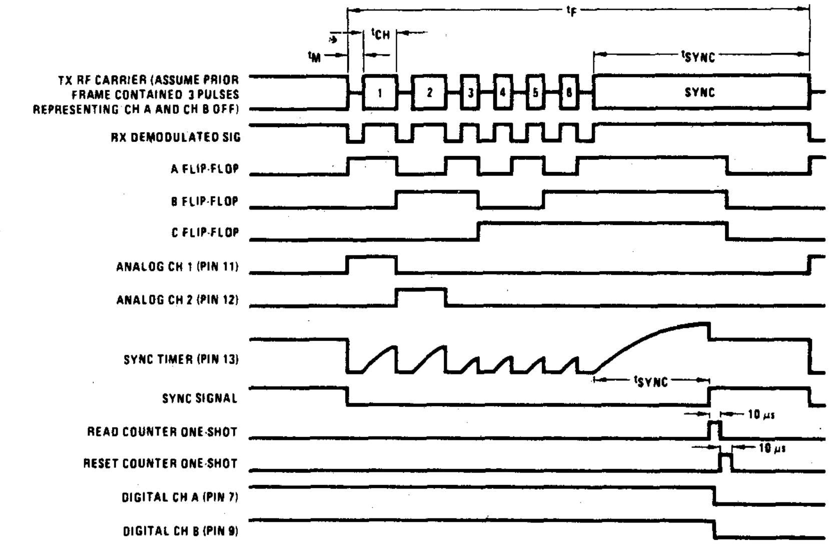
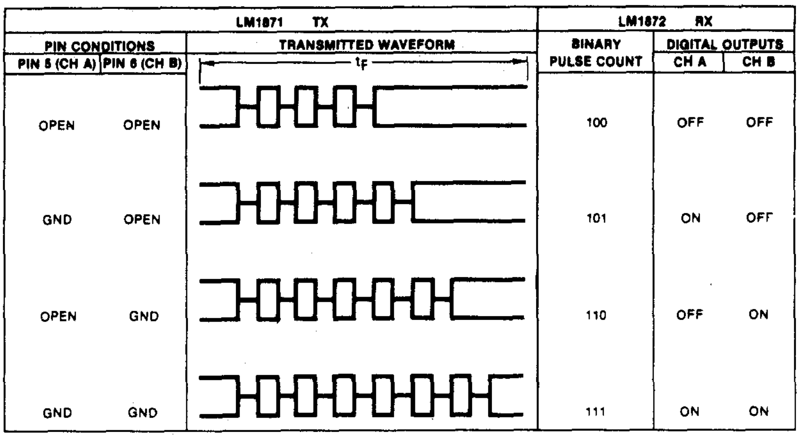


Figure 2(a). Receiver timing waveforms.



LM1871 TX			LM1872 RX		
PIN CONDITIONS		TRANSMITTED WAVEFORM	BINARY PULSE COUNT	DIGITAL OUTPUTS	
PIN 5 (CH A)	PIN 6 (CH B)	tF		CH A	CH B
OPEN	OPEN		100	OFF	OFF
GND	OPEN		101	ON	OFF
OPEN	GND		110	OFF	ON
GND	GND		111	ON	ON

Figure 2(b). Digital channel encoding and decoding via pulse-count modulation.

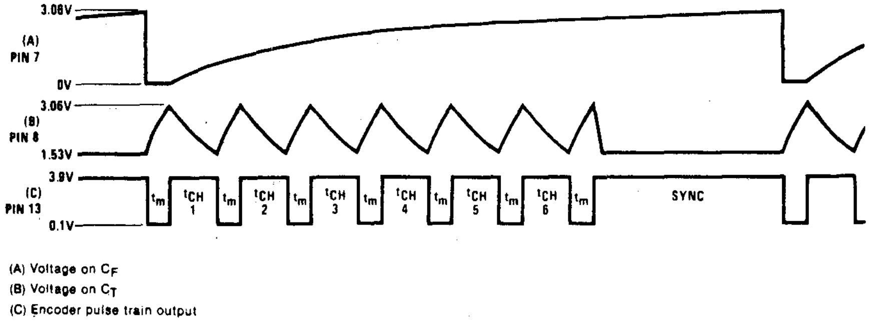


Figure 3. Simplified waveforms for the encoder timing circuits.

each class. Filter types vary from *ye olde Butterworthe* (whose chief merit lies in the simplicity and regularity of its *transfer polynomial*) up to the more exotic *Cauer-Chebychev* filters which give optimum cutoff response but fierce group delay distortion (and hence ring like a bell).

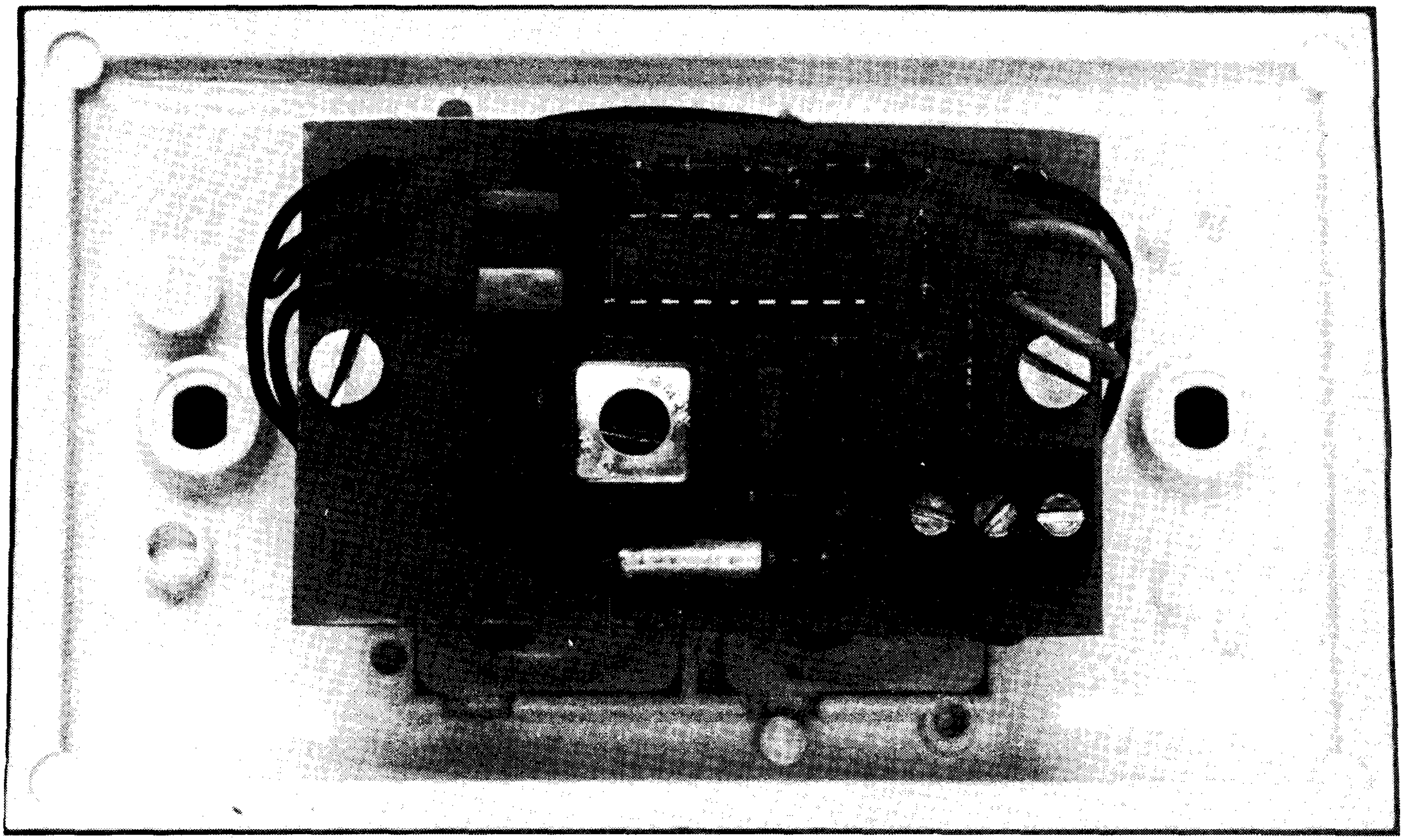
For this application we really need optimum step response, as if the filter rang then, when the lighting intensity was suddenly changed, it would brighten and fade several times before settling down. This would suggest a Bessel filter which has an optimised step response (it doesn't overshoot or ring at all) but a rather slow and soggy frequency response. However, we can do a little better than Bessel's filter by accepting a tiny amount of overshoot (only a few per cent) and using an equi-ripple group delay filter where the filter phase response is allowed to vary a small amount around the ideal linear (Bessel) response and a slight improvement in frequency performance obtained.

The filter actually used is a 5th-order, 0.5° equi-ripple group delay filter which sounds all gosh! gee! wow! fantastic!! but nonetheless actually works just fine. (Linear phase or equi-ripple phase filters also have the advantage that they don't have any very high Q sections and so are a bit more forgiving on component tolerances).

The first section of the filter is a 3rd-order block with the capacitor values shifted to preferred values and the resistor values varied accordingly (this involves fun things like solving a hextic equation (you beat it to death with a calculator!)), but it means you can buy the components in this country. The second section is only a 2nd-order block but it has all the gain necessary to bring the pulse-width modulated dc up to about 0-to-3 volts.

At this stage in the circuit the fact that the information was transmitted at 75 Hz has been removed and all that remains is to relate the dc signals to the mains 50 Hz. In order to do this, IC7, a transistor array, is used to generate pulses on zero crossings of the mains and these pulses are used to generate a ramp which is compared with the dc from the filters (once again, see "How It Works"). After suitable gating to ensure the triac trigger pulses occur when wanted and don't when not (for a pot fully anticlockwise it is essential that the lights be completely out and when fully clockwise they should be full on — care was taken here with end-limit tolerances) the processed analogue outputs are fed to the triac drives.

All four triacs are triggered through opto-isolators to ensure that all the electronics is safe to work on **but beware!! *there is 240* volts on the board!!** The two triacs that are switched from digital outputs have no output filtering as they are triggered on zero crossings, but the two dimmer triacs are filtered to suppress RFI. ●



Control up to four room lights over a twin-wire cable

Here are the full construction and setup details for our room lights controller.

Part 2

Ian Thomas

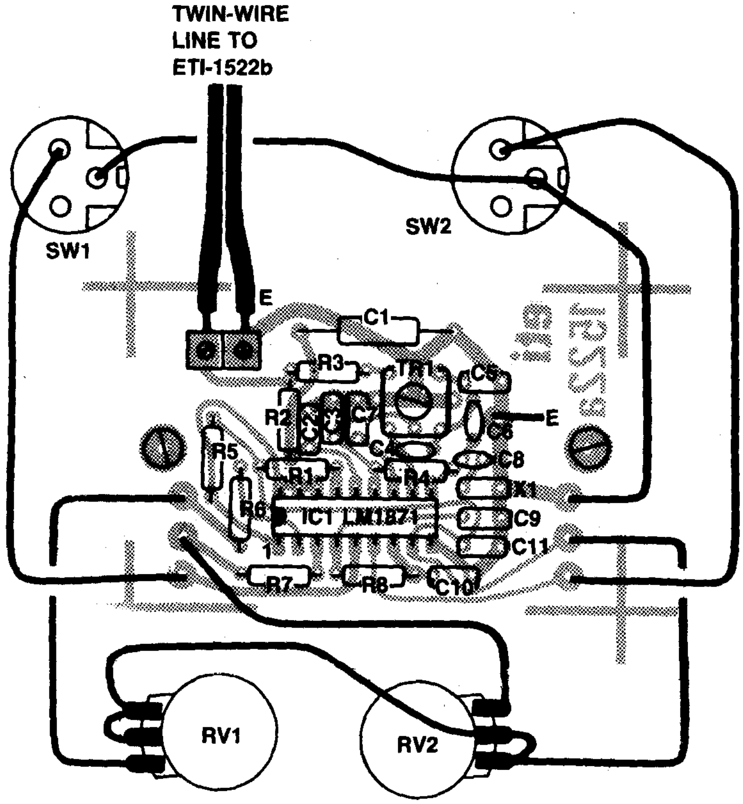
THE SIMPLEST AND EASIEST part to build is the transmitter end which is finally the actual light switch on the wall. The printed circuit board itself is quite straightforward. You need only take care that the integrated circuit is in the right way and that the power supply filter capacitor, C1, has the correct polarity. The correct transformer to use in the oscillator from the pack supplied by Dick Smith (and others) is the one marked "OSC" and has a red tuning slug.

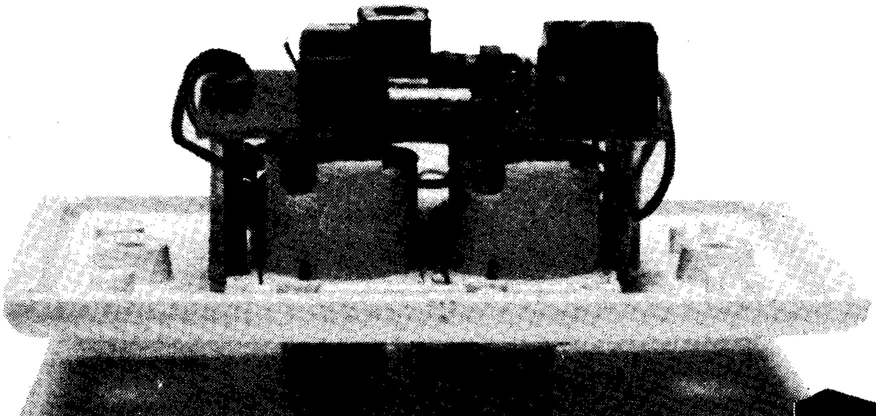
Before mounting any switches on the four-way "HPM" mounting plate it is a good idea to use the printed circuit board as a template to mark where the two mounting screw holes should go. Drill the two mounting holes in the plate to 5/64" (to clear 4 BA) and, if necessary, drill out the printed circuit board itself to the same size. Before mounting any spacers on the printed board or front panel it is necessary to assemble the front panel itself.

The first step is to completely strip down the two "HPM Cat. No. 500 VA" light dimmers. The two switches may be directly inserted in the four way panel as shown in the photo. In order to remove the dimmers from the two-way mounting panel in which they came, first pull off the knob (they're a straight pull with no clamping screws). The dimmers can then be removed from their front panels (once again, there's no magic — just muscle). The next step is to remove the rear cover of the dimmer body itself. Here it is easy to slip a small screwdriver under where the tongue catches in the slot and lever off the rear cover. The whole works of the light dimmer can then be slid from the outer plastic case by pressing on the potentiometer shaft.

Discard all the small bits of grey insulating material around the aluminium triac heatsink. Next, unsolder the three potentiometer leads from the printed circuit board and remove the pot. The plastic main body of the dimmer must next be prepared by cutting it off about 1-2 mm from the step in the body where it locks into the front panel.

Finally, Araldite the potentiometer into the cut-down plastic body so it is located exactly as it was in the original dimmer. *Take exquisite care not to get any Araldite on the pot shaft or in the pot itself.*





Encoder/transmitter. At top is the overlay and wiring diagram, beneath it a view of the switch plate assembly. Note that the twin-wire line to the receiver/triac driver board is polarised. The cable already in the wall will likely have a red and a black wire — use the black one for the line marked 'E' on each board.

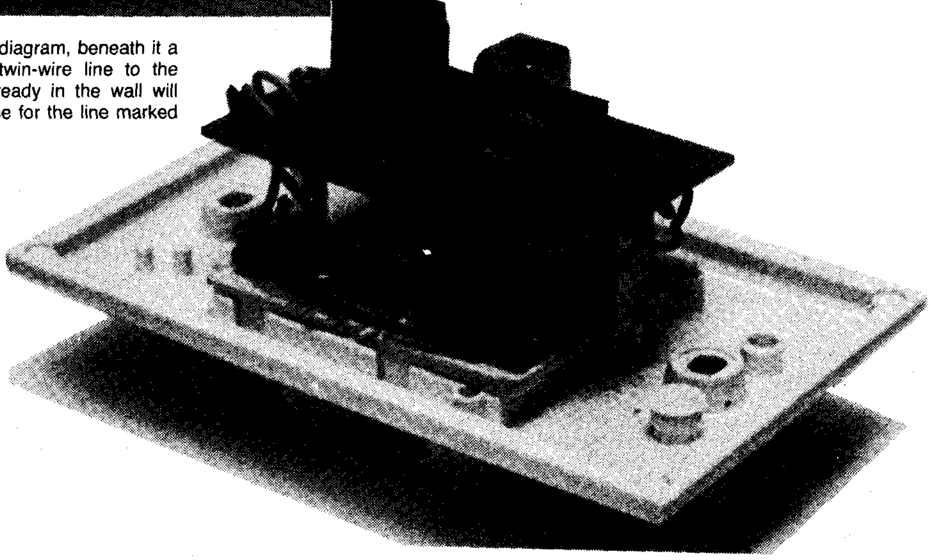
PARTS LIST — ETI-1522A

Resistors	all ¼W, 5% unless noted
R1	150k, 2% metal film
R2	100R
R3	470R
R4	47k
R5	150k, 2% metal film
R6, R7	220k
R8	120k, 2% metal film
RV1, RV2	500k, see text
Capacitors	
C1	22µ/16 V radial lead electro.
C2, 5, 9, 10	100n/63 V Wima type RS21 or equiv.
C3	2n2/100 V Wima type PR2 or equiv.
C4	390p ERO type KP1835 or equiv.
C6	1n ERO type KP1835 or equiv.
C7	10n/63 V Wima type RS21 or equiv.
C8	100p ceramic (NP0)
C11	3n3/100 V Wima type PR2 or equiv.
Semiconductors	
IC1	LM1871
Miscellaneous	
SW1, SW2	from HPM switch/dimmer module, see text.
TR1	local oscillator coil from 455 kHz IF set, DSE cat. no. L-0260, or equivalent.
X1	Murata CSB455E Ceralock ceramic resonator, or Tandy cat. no. 272-1303.

ETI-1522A pc board; HPM dual switch/dimmer module wall plate Series P.774/VH (see text); 3-way pc mount terminal strip; 2 x 25 mm fibre standoffs with 2 x c/s bolts and 2 x cheesehead bolts; hookup wire, etc.

Price estimate: $38-$42

Below. Angled view of the switch plate showing the pots and the board mounting more clearly. Note that the board mounting pillars may be epoxied in place to avoid drilling screw holes through the front of the switch plate. The three-way terminal block was used only because that's what I had on-hand! The overlay shows a two-way block.



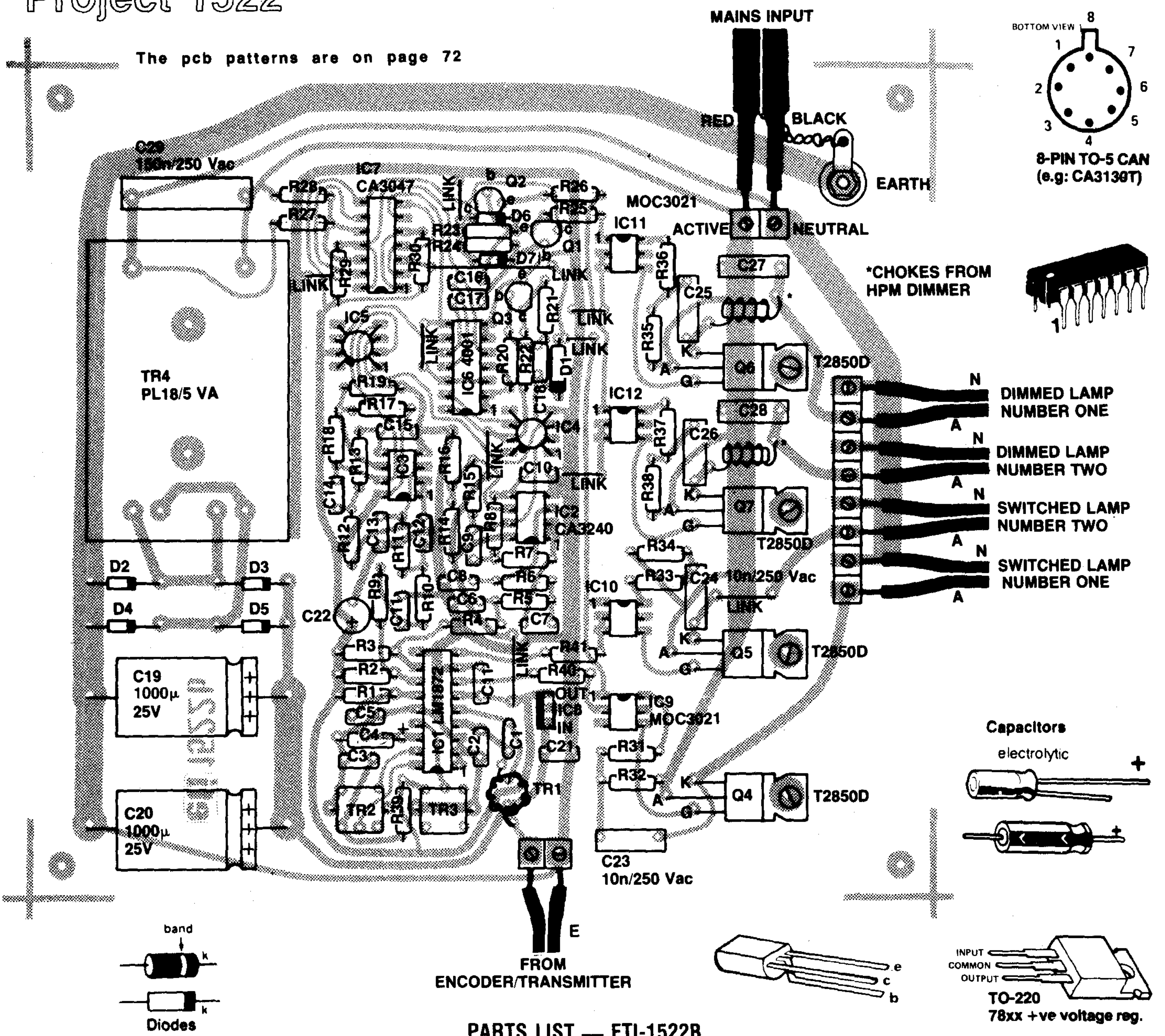
You can now assemble the complete four way panel and wire it up as shown in the photo. Finally, mount the printed circuit board on 1" (25 mm) spacers and the control unit is complete.

The receiver and triac driver is the larger part of the project and I found it easiest (and safest) to assemble and test it in sections.

First, assemble the power supply starting from the mains input connector, mains transformer, TR4, diode bridge D2 to D5, filter capacitors C19, 20 and 21, and finally, the 5 V regulator, IC8. ▶

Project 1522

The pcb patterns are on page 72



PARTS LIST — ETI-1522B

Resistors	all ¼W, 5% unless noted
R1	100k
R2, R3	18k
R4, R9	390k, 2%
R5, 6, 10, 11	180k, 2%
R7, R12	160k, 2%
R8, R13	100k, 2%
R14, R17	10k, 2%
R15, R18	7k5, 2%
R16, R19	1k1, 2%
R20	300k, 2%
R21	1k
R22	56k
R23, R24	10k
R25, R26	150R
R27, 28, 29	220k
R30	56R
R31, 33, 36, 37	330R
R32, 34, 35, 38	470R
R39, 40, 41	100R
Capacitors	
C1	390p poly, ERO type KP1835 or sim.
C2, 3, 6, 7, 10, 11, 12, 15, 21	100n/63 V, 5% Wima RS21 or equiv.
C4	1µ/6 V axial lead electro.
C5, C18	47n/63 V, 5% Wima RS21 or equiv.
C8, 13, 16, 17	10n/63 V, 5% Wima RS21 or equiv.
C9, C14	22n/63 V, 5% Wima RS21
C19, C20	1000µ/25 V axial lead electros
C22	100µ/10 V radial lead electro.
C23, 24, 25, 26, 27, 28	10n/250 Vac mains suppression caps
C29	150n/250 Vac mains supp. cap.
Semiconductors	
D1, 6, 7	1N914, 1N4148
D2, 3, 4, 5	1N4001, 1N4002 etc
IC1	LM1872
IC2, IC3	CA3240E
IC4, IC5	CA3130T
IC6	4001B
IC7	CA3046
IC8	7805
IC9, 10, 11, 12	MOC3021
Q1, 2, 3	BC549, BC109 etc
Q4, 5, 6, 7	T2850D RCA triacs
Miscellaneous	
TR1	Philips toroid, 9 mm O.D. by 3 mm thick, 3H1 material; or Neosid toroid 6.35 mm O.D. by 1.52 mm thick, F9 material.
TR2, TR3	IF/DET. transformers from 455 kHz IF set, DSE cat. no. L-0260, or equivalent.
TR4	Ferguson PL18/5VA or equiv.

ETI-1522B pc board; housing to suit (see text); four 12 mm standoffs with bolts and washers; pc mount screw terminal strips (1 x 8-way, 2 x 2-way); 0.4 mm enamelled copper wire; tinned copper wire for links; 4 BA bolt, nuts & solder lug (earth terminal); 4 x 4 BA bolts and nuts; six clamp-type grommets or similar, etc.

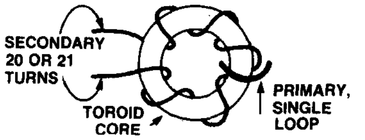
Price estimate: $90-$100

Next, cover all tracks that carry mains voltages with insulating tape so that when the printed circuit board is being tested your good health and longevity is not at risk (joking aside this is a *very* good idea as if you try to build the board up and get it running without taking any precautions you will get bitten at the very least!)

Power-up the board with only the power supply assembled and check that the output from the voltage regulator is 5 V ± 0.4 V. (It is exasperating beyond belief to assemble a large board only to see it all destroyed because the voltage regulator was faulty or, more likely, there was a solder short).

If all is well, turn off the power *and pull out the plug* as the bloke who wired up your house wouldn't be the first to get active and neutral reversed.

CONSTRUCTION OF TR1



Core:	**9 mm O.D. Philips toroid, about 3 mm thick, of 3H1 material (A_L = 800), or 6.35 x 1.52 mm, F9 Neosid toroid (28-501-36).**
Wire:	**Light duty hookup wire.**
Primary:	**One turn.**
Secondary:	**20 turns (Philips toroid) or 21 turns (Neosid toroid).**

Now proceed to assemble all parts of the receiver section. The transformer that recovers the 455 kHz data from the transmitter power supply line has to be wound but is only 20 turns of about 22-26 gauge wire evenly distributed around a Philips 9 mm (O.D.) toroid of 3H1 ferrite. (These toroids are painted orange with one side of the toroid painted various other colours to indicate the permeability of the ferrite material — it doesn't matter what the permeability is). The secondary winding of TR1 is even easier; just one turn, which carries the +12 V to the transmitter section (and also holds down the toroid). Make sure that TR2 is the IF transformer with the yellow-painted tuning slug and TR3 has the white one. It is important that C22 be assembled at this stage.

After the receiver is assembled the transmitter and receiver can be tested and aligned to the same frequency. It is not all that important that the transmitter run at exactly 455.000 kHz, but merely that the receiver be tuned to the same frequency as that sent.

The first thing to do is set up the transmitter. Connect the transmitter to the receiver via the two printed circuit mounting terminals making sure you have the correct polarity (+12 V on the transmitter is nearest the corner and is nearest the IF transformers on the receiver). Then, disable the data transmission from the LM1871 by shorting pins 4 and 12 (I found it easiest to temporarily solder a short piece of wire between the two pins). Power up the combination and check that there is a continuous signal on the +12 V line. If you have a counter, measure the frequency of this signal and adjust TR1 of the transmitter until it is 455 kHz. If you don't have a counter then wind the adjusting slug all in (but gently! these things are not unbreakable) then come out about 1-1½ turns. The oscillator showed the characteristic that it could not be pulled much below 455 kHz but could be pulled until the ceramic resonator lost control completely on the high side. Adjusting this way will put you slightly below 455 kHz but not too far.

The receiver can now be aligned to the transmitter frequency by monitoring the agc voltage that appears on pin 16 of the LM1872. With the data still disabled on the transmitter, adjust first TR2 and TR3 so that the agc voltage is a *minimum*. This should set the passband of the receiver correctly as both transformers are only single tuned. If you have an oscilloscope then the tuning procedure is to monitor pin 17 and adjust TR2 for a maximum then monitor pin 15 and adjust TR3 for a maximum. If your oscilloscope does not have ÷ 10 low input capacitance probes, it is necessary to monitor the voltages through a 4.7 pF capacitor so probe loading does not pull the centre frequency.

Now that the transmitter and receiver are aligned, the short between pins 4 and 12 of the LM1871 can be removed and the two switches should work. Also if the pullup resistors R2 and R3 are in, pulses containing the analogue info should be visible on pins 11 and 12.

The rest of the analogue circuitry can now be assembled starting with the two active filters. Insert ICs 2 and 3 and all the resistors and capacitors associated with them. It will be necessary to insert the jumper near the 5 V regulator (see photo), but don't put in any of the other jumpers yet.

When the two active filters have been completely assembled that section of the receiver can be tested. Power up the system and monitor pin 7 of either IC2 or IC3. When the dimmer controls on the transmitter are varied (trial and error will show which control affects which output) the appropriate output should vary between 0 (actually about 50 mV — this is why it is essential to use an RCA CA3240E for ICs 2 & 3) and 3 volts. There should be no interaction whatsoever between the two controls or between the controls and the two switches. If there is, then there's something wrong.

The next part to do is the 50 Hz zero crossing detector and ramp generator with **its associated comparators and gating.** Assemble the rest of the circuit up to the optocouplers. When the circuit is powered up pulses about 50 μs wide and negative-going should be on IC6 pin 4, and positive-going on pin 3. The pulses are impedance transformed through three transistors in IC7 to give high current, positive-going pulses out of pin 3 of IC7. There should be a negative-sloping ramp of about 2½ V peak at pins 3 of ICs 5 and 6, which are the two comparators that compare the dc signals out of the filters with the mains synchronised ramp (see "How It Works"). Looking at IC6 pins 11 and 12, you should see square waves whose mark-space ratio is varied by the transmitter controls.

Finally, assemble the optocouplers, *noting that pin 1 for the optocouplers is rotated 180° from all the other ICs.* Also, assemble all the dV/dt protection circuitry and the triacs themselves. The RCA T2850 triacs that I used have the wonderful advantage that the mounting tab is electrically isolated from the pins so you can do as you like with them. If the triacs are simply screwed down to the board it can handle up to about an amp or so without getting too hot.

If you want one circuit to carry more than this it is quite easy to make up a right angle bracket to act as a heatsink. As the two on-off circuits are being switched on zero crossings they do not tend to generate RFI but the two that act as dimmers do and some form of filtering is necessary to suppress the edges if you don't want to drive your neighbours (and yourself) crazy with buzzing radios.

Fortunately, the filter inductors could be saved from the triac dimmers that were originally cannibalised to get the control pots. Unfortunately, HPM chose to use 1/32" thick printed circuit board material for the dimmers so most of the other components could not be salvaged, but by unwinding one turn from each end of the toroid winding, they can still be used. After soldering in the toroidal inductors, glue them down with a generous dob of **Silastic** or somesuch. Solder-in the output 8-way connector and your controller is ready for final test. The output terminals alternate between neutral and switched, with the two pairs nearest the receiver and away from the mains input being the on-off lines and the **two pairs nearest the mains input being the 'dimmed' lines.**

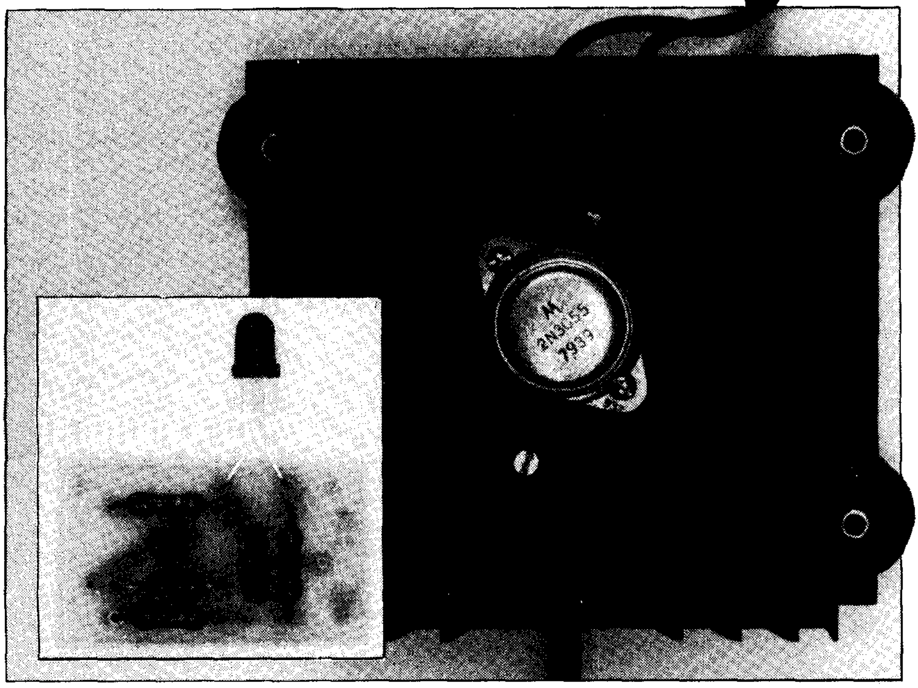
Connect a light bulb to each output in turn and ensure that the appropriate control works (at the same time you can establish which control operates which output).

Finally, the whole receiver board can be mounted in an insulated box. As the receiver is (presumably) to be left in the ceiling the size of the box doesn't matter so, as I always find it infuriating to have to work with tweezers and magnifying glass I chose a container of most generous proportions namely, a "Clipsal" adaptable box 300 mm x 200 mm x 150 mm, which gives plenty of space all around the receiver board.

Mount the board towards one end of the box with the 8-way terminal block away from the end of the box. This gives plenty of space for the four-wire pairs from the lights to connect to the board. Finally, cut holes with a hole saw opposite the three terminal blocks to allow cables into the box and you are ready to start having fun crawling around in the ceiling connecting everything **up. Note that the wire pair to the wall switch is polarised. The line in the wall will likely have a black and a red wire. Connect the black to 'E' on each board. It only has the isolated 12 V on it now. By the time** you cut and reconnect all the wires in the ceiling (or have a licensed electrician do it if you are not qualified to do so yourself), you will probably find that you need a few junction boxes and some spare lighting cable, so its a good idea to plan things out carefully first. ●

Project 274

A *damn fast* NiCad battery charger



This project is specifically designed for modellers, photographers and hobbyists who make heavy demands on NiCad batteries quite routinely. There's nothing more frustrating than having your RC model run out of juice as it runs out of sight, or your flash run out of flash at an inopportune moment. If you use NiCads and need a charge — but quick — this project is for you!

Jonathan Scott

SMALL Nickel-Cadmium cells are often employed to replace frequently-used dry cells because they work out cheaper after a lot of recharges, and also because they save you a lot of walking to the corner store to purchase replacements.

There are, however, some properties of these types of cells which enable them to perform tasks other batteries cannot. Most notably, they have a lower internal resistance for a given cell size: A typical penlight NiCad has twenty times less internal resistance than its equivalent dry cell. This means that a lot of power can be drawn from them in a short space of time. They can thus perform a task which demands lots of power over a short period out of a small set of cells. There is a price to pay for this; namely, short cell life. They also exhibit a low total ampere-hour (Ah) capacity under fast discharge conditions.

The most notable use for these properties is the powering of models, particularly aeroplanes and racing cars. Such devices are expected to weigh little and develop a lot of engine power over a short space of time. A set of dry cells simply cannot achieve this. An electric aircraft will typically carry one or two cells and flatten them inside three minutes; a land craft may carry five or so large cells and flatten these inside fifteen minutes. Of course, the cells suffer a great deal for this kind of treatment and tend to expire after ten to twenty uses in the three minute case, or twenty to fifty uses in the ¼-hour case. There are two upshots of this; firstly, the user typically wants to be able to recover and re-use the cells often in one day, and secondly, he does not really care if the recharge process thrashes the cells a lot, because their discharge is going to kill them fairly quickly anyway.

Toward the goal of charging cells quickly, ETI published a Fast NiCad Charger (Project 563) some time ago (July 1980). This was a mains powered device which incorporated a timer and some sophisticated electronics to make the unit fairly foolproof. While there is no doubt that this project found a home in many a modeller's kit, it was designed at the general level, rather than a specific market. There is a need for a somewhat simpler and yet more powerful charger, designed to run off a car battery or similar portable power reserve, capable of substantially more rapid a current delivery again. This project is it.

Let me stress once again that this unit is ***not for general use;*** there is a detrimental effect on healthy cells when asked to deliver large currents over short periods. This project also does not have the foolproof nature (or the complexity) of the ETI-563 Fast Charger and can completely cook a battery if left on too long. It is designed for use out in the field where the cells it is charging are needed *damn* fast, and at any price. For a more detailed discussion of the merits and limitations of fast NiCad Charging, you are referred to the article accompanying the ETI-563 Fast Nicad-Charger.

Design details

The circuit is basically a constant current source, delivering a preset current (up to 8 amps) into a load, using a dc voltage source of about three volts more than the voltage which will be required by the load. It uses only common components and half watt resistors so can be constructed with a minimum of effort. Notably, no high power "current sense" resistor is necessary as these often tend to be tricky things to purchase or build — where do you get a 0.075 ohm, 5 watt resistor? All that is necessary for its construction can be purchased from just about any electronics supplier in the country.

Construction

Before proceeding with the construction of this project there are two things which must be decided. The first is the current you wish to set the regulator to deliver, and the second is the scheme you wish to use to protect the circuit against reverse connection of the supply (typically a car battery). The former is a function of the ampere-hour capacity of the cells you will be charging.

I envisage that the regulator will be used in a fairly rugged environment for charging a single type of cell; therefore the current is set to a predetermined value, eliminating the cost and unreliability of a switch and set of resistors, not to mention the possibility that the switch will be miss-set in operation.

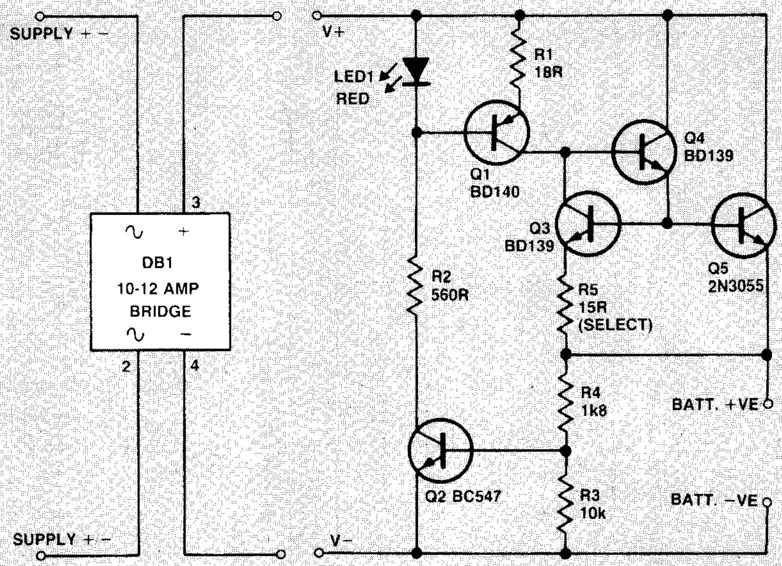
Should you wish to include one, there is nothing to prevent you adding a double or multiple throw switch and a selection of resistors to give a selection of current ranges, but I will proceed here assuming that there will be one current only required. (To effect range selection all that is needed is to switch the emitter resistor of Q3 using a toggle or rotary switch; a pot is not recommended, though a 100R wirewound type would be sufficient).

It seems from experience that the highest safe charge rate for a NiCad is around 4C (C is the cell's Ah capacity) or that current which equals the ampere-hour rating multiplied by 4/hr. Thus, a 450 mAh battery should be charged for up to about 20-25 minutes at a time at just under two amps. An 1800 mAh battery would accept charging at just over seven amps.

The project described here is capable of up to eight amps guaranteed, and may be 10 A typical. The exact value depends upon many variables concerned with the particular parameters of the specific transistor used for Q5. For a 2N3055, as specified, I have given approximate values required for R5, but the exact value will probably need to be selected, as indicated in the circuit diagram. Fifteen ohms gave 6 A on my prototype. Eighteen ohms gave 5 A, and twelve ohms gave 7 A. To get down to 2 A required thirty three ohms. Using three values as a guide, choose an initial value for R5, but remember that this value may have to be changed later.

The second thing to be decided, once you have chosen the current required, is the protection scheme. There are three ways you can tackle this. I think it would be foolhardy, to say the least, not to include some protection from reversed supply, particularly as the unit is to be used in a hurried situation in the field. The first method is a single diode, the second is to use a diode bridge, and the third is to use a relay.

Clearly, this decision will be influenced by the cell or battery voltage. A NiCad being fast charged drops up to 1.5 volts. The actual regulator section requires typically three (worst case four) volts 'overhead'. If you are using a car battery it can be expected to deliver almost 12 ▶



HOW IT WORKS — ETI 274

Referring to the circuit diagram, it can be seen that Q4 and Q5 form a Darlington series-pass regulator element. Q3 acts as a comparator, while Q1 acts as an active current source load for Q3. Q2 provides short circuit foldback limiting, while LED1 indicates correct operation and provides a reference.

Initially, consider that there are a few volts across the battery connected to the ouput. Q2 is biased on via R4 and has a collector current of typically 15 mA or so. This current is set by R2. Assume that the supply is around 10 to 12 volts. Thus, Q1 will be biased on. If Q1 is in the active state it acts as a current source delivering approximately 55 mA to the collector of Q3 and base of Q4. Q4 and Q5 will be biased on and hence their combined collector currents will be delivered to the battery.

For a collector current of five amps, the internal resistances of a 2N3055 gives a base-emitter voltage not of the 0.8 V value which might be expected from an ideal exponential device, but more typically 1.2 volts. This circuit will use this internal b-e resistance, already allowed for in the transistor's dissipation specification, as the current sensing element.

Now, recall that Q1 is delivering a fixed current to be divided between the base of Q4 and the collector of Q3. Q3, which is in close thermal contact with Q5, has a Vbe which is nearly the same as, and tracks that, of Q5. The voltage component of Q5's Vbe, which is due to its emitter current times the internal b-e resistance mentioned above, is substantially placed across R5. Hence, the collector current of Q3 is nearly a constant multiplied by the emitter current of Q5, the current delivered to the load (battery).

There is an equilibrium point where the current drawn by the load produces a collector current in Q3 which exactly leaves sufficient current left over from that suplied by Q1 to feed the base of Q4. Should the load current rise above this point the collector current of Q3 would rise also, removing some drive current from Q4, reducing the load current. Conversely, if load current falls, Q3 leaves more current for Q4, restoring the load current. Hence, current regulation is achieved. R5 affects the ratio of load current to Q3 collector current and so may be selected to define the load current at equilibrium.

Two further effects are utilised. Should the load voltage fall below about 1.1 volts, the level for one cell, Q2 will be biased off, extinguishing LED1 and shutting down the current regulator Q1. This reduces output current, effectively shutting the circuit down. This will occur should either a short circuit or a reverse battery connection occur on the output. It is thus not possible to reverse charge the cell(s) or to overheat the regulator by operating into a short. This shutdown condition is betrayed by the LED extinguishing. In addition, if the load voltage rises too high for the regulator to run properly, as is the case if there is a bad or open connection, Q1 will saturate, reducing the voltage across LED1, again extinguishing it. Thus, the LED indicates successful delivery of current to the load.

If a diode bridge is installed in the supply line it does not matter which way round the supply is connected. A single diode will simply shut the circuit off if connected wrongly, but drops about 0.8 volts, compared to 1.6 volts with the bridge. If neither of these voltage drops is acceptable, a relay may be used to protect the regulator from reversed supply. The regulator requires about three volts of overhead, so the protection scheme must be selected with the available supply voltage and the required load voltage in mind, as described in the text.

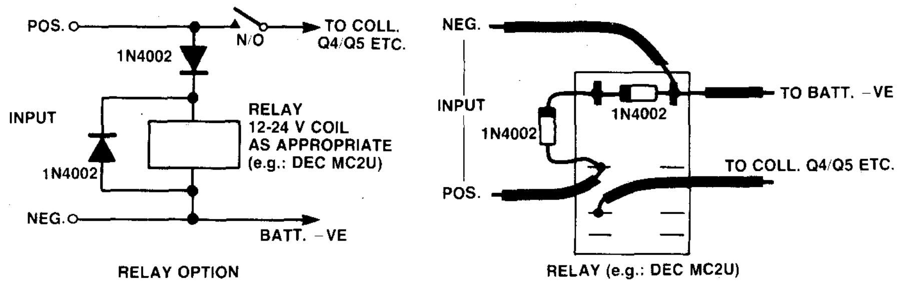


Figure 1. Although the relay option is expensive, it can charge a large number of cells at one time. The voltage drop is negligible and the power dissipation is low.

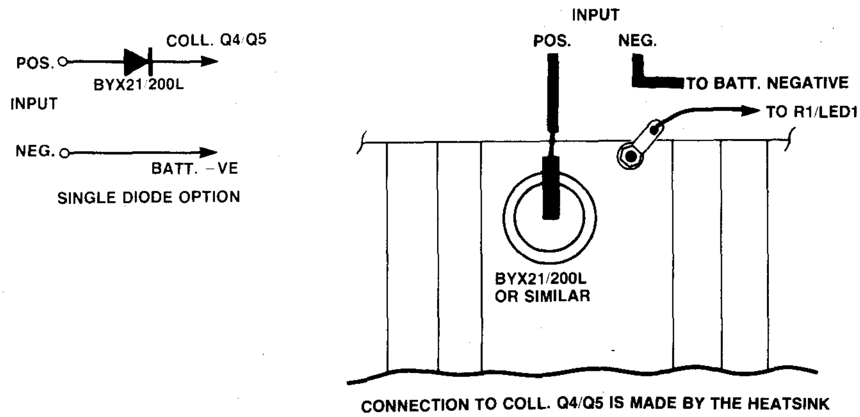


Figure 2. The single diode option is cheap, has a voltage drop of about 0.8 V and average power dissipation.

volts. Hence, it may be shown that a relay which drops negligible volts allows five cells in series (nominally a 6¼ volt stack) to be handled from one car battery, a single diode allows four, as does a bridge — just. (The sum here is V supply-4 divided by 1.5 for the relay, Vs-4.9 divided by 1.5 for the single diode, and Vs-5.8 divided by 1.5 for the bridge).

Although the bridge costs a little more than a single diode it allows you to ignore the polarity of the supply connections as the circuit effectively 'rectifies' the input to give the correct polarity irrespective of supply orientation. If you can afford the voltage drop, it is the best method, particularly as bridges of the appropriate power rating are simpler to mount and connect to than their equivalent diode counterparts. The relay option (see Figure 1) is expensive and is really only recommended for those situations where it is the only resort to obtain the capacity to handle the required number of cells. The supply can be up to 24 volts nominal, so this should not be necessary.

I recommend the bridge option as this seems the best and most convenient choice. It entails a few dollars more in cost than the single diode, but it is easier to mount and easier to use.

Having decided upon the circuit elements, the current to be delivered and the voltage into which it will be delivered, you are fixed. The next step is to figure out how much heatsink is needed. If you are using a 12 volt supply and delivering 6 A or less a '4"' heatsink is adequate. (These are generally rated to dissipate 2° C/W in still air). However, if the product of supply volts and current is in excess of about 70, a larger heatsink is to be recommended. Remember that the circuit may have to dissipate almost that figure in watts worst case, so it is a good idea to have the capability. In any case, if the 2N3055 case gets hot enough to boil water the heatsink is too small! (It is not unusual for it to get rather too hot to touch when working very hard, so don't let that worry you).

You are now ready to obtain the components and commence the actual construction. The first step is to drill the heatsink. If you are duplicating the prototype, follow the diagram here. Otherwise, you can set out the parts as you see fit. It is good practice to put the main heat disspiating element, the 2N3055, near the centre of the dissipating surface.

I used terminals on the output of the unit and had a fixed automotive grade ('heavy duty') cable for the battery connection, but you should use whatever connection will best suit your application. For instance, you may have some standard kind of plug to fit your models, or whatever, or perhaps you many want to use car battery bolt-on connectors on the input. Be sure to make provision to clamp any cables. Also remove any burrs and dags that could penetrate insulation washers on the transistors.

Next, fit the transistors and diode or bridge, etc, to the heatsink. Fit the terminals and/or clamp the cables in place. When all the parts that need to be secured to the heatsink have been bolted in, put the assembly aside. Now solder the four resistors and two transistors (Q7, Q2) to the small pc board, as shown in the overlay. This can be mounted either on the heatsink (if it's big enough) or inside a zippy box bolted to the heatsink.

Finally, interconnect all the components as shown in the wiring diagram. It is convenient if Q3/4/5 have been mounted close enough together to allow their leads to join directly. Resistor R5 is wired directly in place.

After carefully checking the wiring (remember that a mistake can easily incinerate the whole lot in one fell swoop) apply the supply. Confirm that the 'Batt + VE' terminal is indeed at nearly the full supply. Connect a load. If you have an old set of NiCads, or a headlight globe, use this instead of a good set at first. Measure the current being delivered. If it is too high, replace R5 with a resistor of larger value, or vice versa. You will be able to pick the correct value on the second or third attempt no matter how far out the original estimate. Check that either shorting the output or leaving it open causes LED1 to go out. If this is the case, all is well and you're set to go. ●

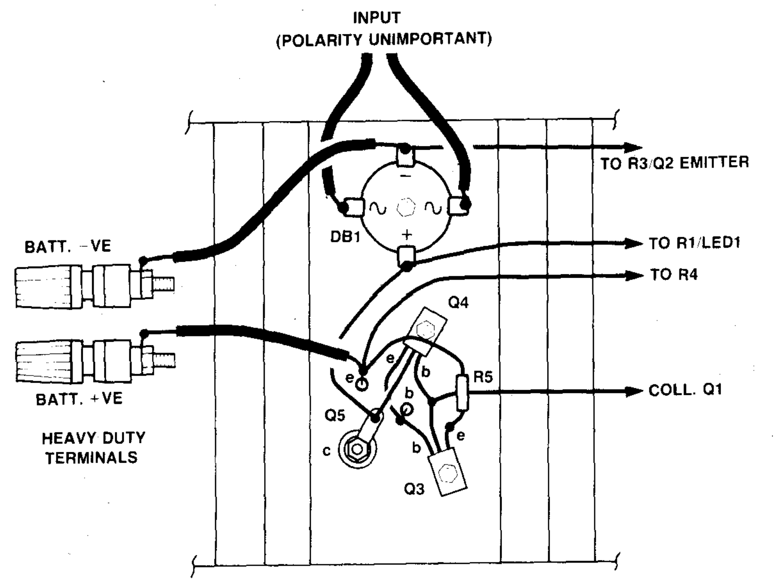
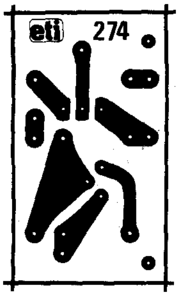
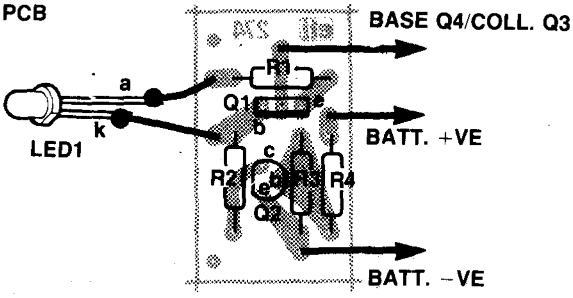


Figure 3. The diode bridge option costs a little more than the single diode but its advantage is that it can be connected in either way ignoring the polarity of the supply connections. It dissipates more power than the other options and has a voltage drop of about 1.7 V.



ETI-274 PCB



PARTS LIST — ETI-274

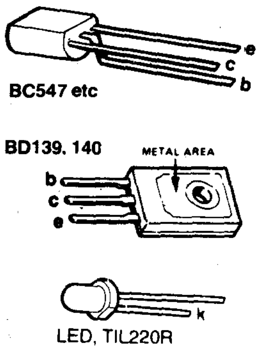
Resistors	all ½W, 5%
R1	18R
R2	560R
R3	10k
R4	1k8
R5	12-33R, see text
Semiconductors	
DB1	10-12 A bridge rectifier (PA40F or similar)
LED1	TIL220R red LED
Q1	BD140
Q2	BC547, BC107
Q3, Q4	BD139
Q5	2N3055

Miscellaneous

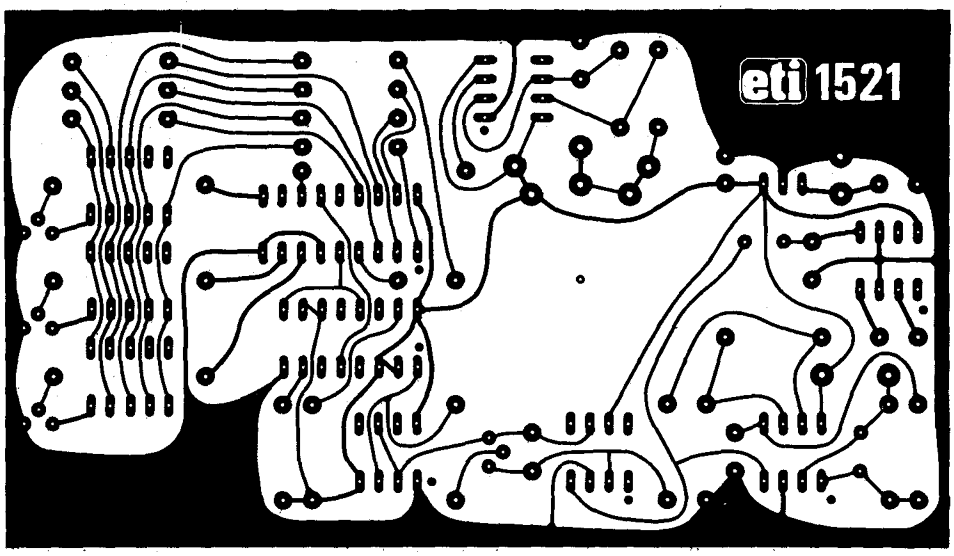
ETI-274 pc board; UB2 zippy box (if required) 60 x 113 x 196mm or similar; 100mm heatsink or larger; heavy duty terminals; heavy duty figure-8 cable (coded red/black); TO-220 transistor insulating and mounting hardware (two sets); TO3 mounting hardware; hookup wire — medium and heavy duty; nuts, bolts, etc.

Price estimate $22-25

COMPONENT PINOUTS



PCBs



Project 265

The ‘power down’ mains appliance timer

Have you ever turned on your electric radiator to warm a room in the morning and forgotten to turn it off on your way out? What about the patio light — ever turned that on and forgotten to turn it off until the next day? This project will not only solve those problems, but has many applications besides.

Geoff Nicholls

THIS IS a press-button mains appliance timer. You plug the project into a wall socket, plug your appliance into the project, then press the button to turn the appliance on. Some predetermined time later, the project will automatically *'power down'* (or turn off) your appliance.

No doubt you're familiar with those time switches installed in the stair wells of apartment buildings that control the stairway lights. You press the big button and the lights come on just long enough for you to *not quite* make it up the stairs! These devices employ a mechanical timer, their major problem being that, with use, the period decreases. In addition, you can't preset them to a convenient time over a wide range.

Many 'deluxe' electric heaters these days incorporate a timer of some sort so that the heater can be turned on for a preset period, then turn itself off. 'Super deluxe' models go so far as having a timer with digital display and programming facilities to turn it on and off whenever you like each day for a fortnight! That's probably going a bit far for many applications, though.

Getting 'closer to home', so to speak, take the case of an EPROM eraser. This basically comprises an ultraviolet lamp and a period timer. You bung your EPROMs under the lamp and turn on the timer. The timer then turns the lamp off the required period later (typically, 20 minutes).

In photographic work, film and print exposure times are often handled with a simple period timer. When making multiple exposures for comparisons, etc, binary-related exposure times are frequently used, e.g: print exposures of eight minutes, then four minutes, then two minutes, etc.

This versatile little timer will handle all the above applications and can be configured to suit a huge variety of other applications, probably only limited by your imagination.

This project can be set up for timing periods ranging from one minute up to at least 50 hours. Although I haven't tried it, it is certainly possible to extend the period to around 400 hours (16-17 days). Binary 'segments' of the basic period can be selected by the simple addition of a suitable switch. The project is low in cost and can be built into an appliance if you so wish.

Design

The unit is quite straightforward. Figure 1 shows a block diagram. It consists of an oscillator, a divider, a flip-flop, a relay driver and relay. The relay contacts are used to connect and disconnect the mains power from an attached appliance.

The oscillator output is divided down 8192 times. The divider's output drives the 'reset' input of the 'reset-set' (RS) flip-flop. The flip-flop has two outputs — A and B. In the initial, or reset, state, output A is high, resetting the divider in preparation for counting. Output B of the flip-flop is low and the relay is not operated.

When the start button is pressed, the RS flip-flop is 'set'. Output B goes high, operating the relay and turning on the appliance connected via the relay. Output A goes low, enabling the divider to count down.

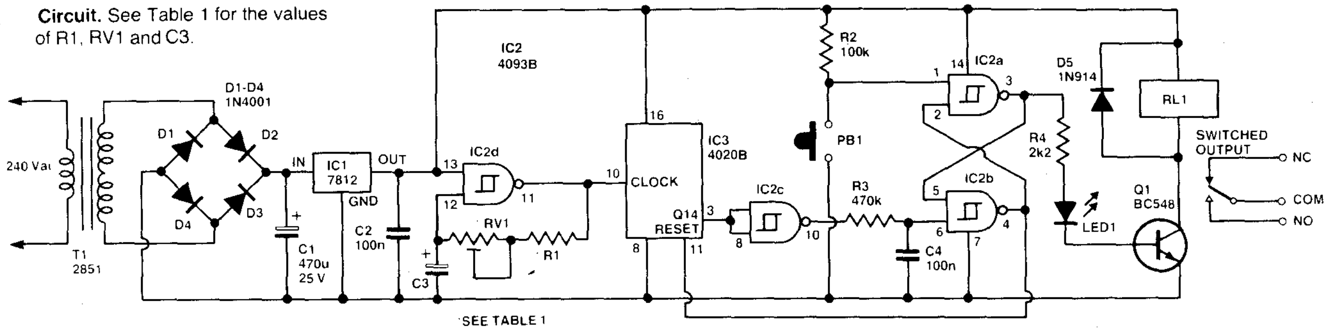
At the end of its count, the divider's output goes low, resetting the flip-flop. Output A goes high again, stopping the divider, and output B goes low. The relay then drops out, turning off the appliance connected via its contacts.

The oscillator's frequency will determine the basic period. Because the division ratio is so high, minor drifts or variations in the oscillator frequency will not materially affect the timing period, hence a simple oscillator can be used.

As the required timing period is determined by R1, RV1 and C3, the values you need for these components should be determined from Table 1 before commencing construction. It would be reasonable to expect a kit supplier *not* to include these in a kit, or to perhaps only include, say, a 1u RBLL or tantalum for C3 and perhaps a 1M trimpot, as these would cover a wide range of timing periods, leaving the choice of R1 to you.

Note that C3 should either be a tantalum type or single-ended 'low leakage' electrolytic for repeatable results. ▶

Circuit. See Table 1 for the values of R1, RV1 and C3.



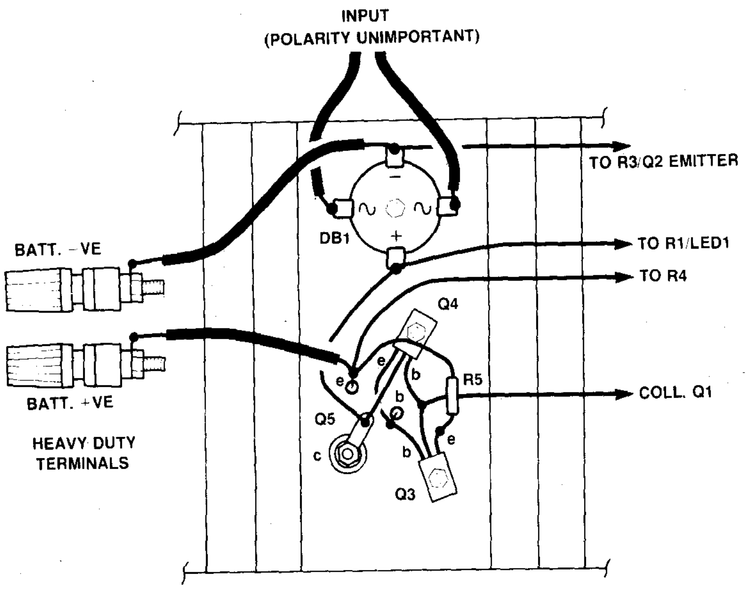


Figure 3. The diode bridge option costs a little more than the single diode but its advantage is that it can be connected in either way ignoring the polarity of the supply connections. It dissipates more power than the other options and has a voltage drop of about 1.7 V.

PARTS LIST — ETI-274

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R4	1k8
R5	12-33R, see text
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LED1	TIL220R red LED
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Miscellaneous
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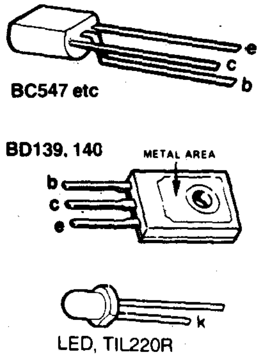
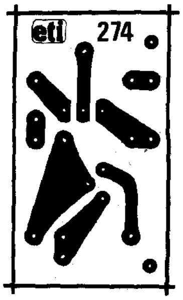
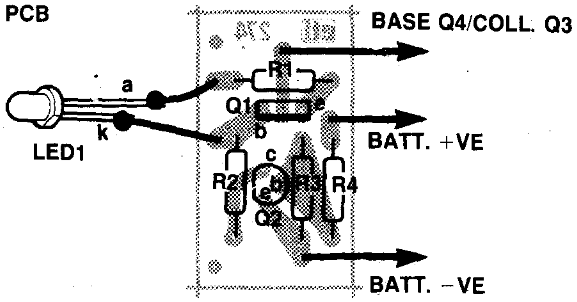
Price estimate $22-25

COMPONENT PINOUTS

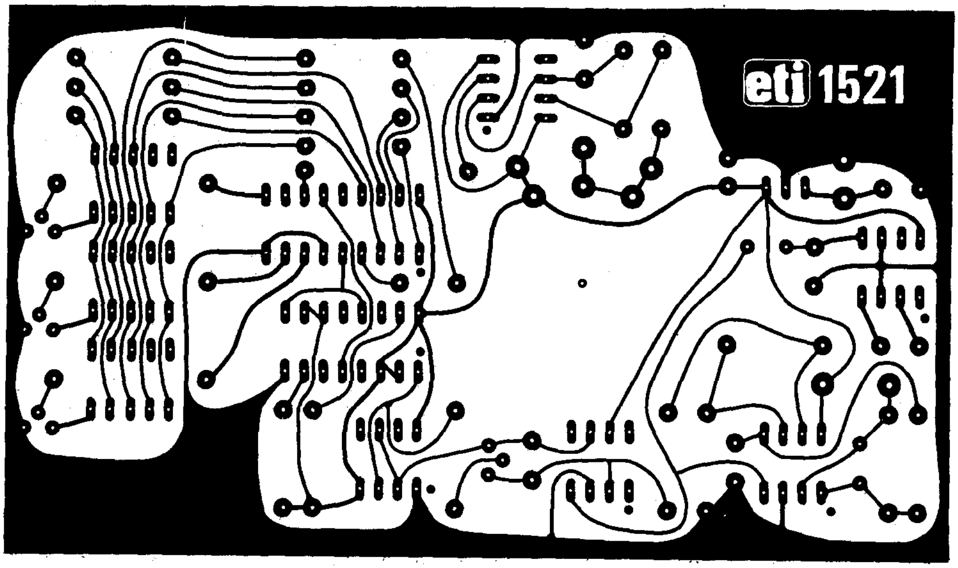


ETI-274 PCB





PCBs



The 'power down' mains appliance timer

Have you ever turned on your electric radiator to warm a room in the morning and forgotten to turn it off on your way out? What about the patio light — ever turned that on and forgotten to turn it off until the next day? This project will not only solve those problems, but has many applications besides.

Geoff Nicholls

THIS IS a press-button mains appliance timer. You plug the project into a wall socket, plug your appliance into the project, then press the button to turn the appliance on. Some predetermined time later, the project will automatically *'power down'* (or turn off) your appliance.

No doubt you're familiar with those time switches installed in the stair wells of apartment buildings that control the stairway

sure times are often handled with a simple period timer. When making multiple exposures for comparisons, etc, binary-related exposure times are frequently used, e.g: print exposures of eight minutes, then four minutes, then two minutes, etc.

This versatile little timer will handle all the above applications and can be configured to suit a huge variety of other applications, probably only limited by your imagination.

ting the divider in preparation for counting. Output B of the flip-flop is low and the relay is not operated.

When the start button is pressed, the RS flip-flop is 'set'. Output B goes high, operating the relay and turning on the appliance connected via the relay. Output A goes low, enabling the divider to count down.

At the end of its count, the divider's output goes low, resetting the flip-flop. Output A

Construction

I built one prototype and mounted it in a plastic case, which you see in the photographs here, and another unit which I mounted inside an appliance (ask no questions and . . .)

I used an all-plastic Unibox (P/N144) measuring 135 mm long by 100 mm wide by 50 mm deep. (Magraths in Melbourne are a major supplier of these.) It has ample room inside. You could use a UB-1 zippy box (50 x 90 x 150 mm), but an all-plastic case is recommended for safety's sake. Jaycar stock a range of smart, all-plastic (ABS) cases in various colours. The HB6150, 1, 2, 3 series (orange, grey, blue, black) would suit.

First thing to do is determine the mounting positions of the printed circuit board and transformer. Lay the unassembled pc board and the transformer in the base of whatever box you're using and mark the positions of the mounting holes.

Then mark out suitable positions for the mains cable entry, the pushbutton, the LED and the mains socket. For the mains cable entry, I used a Heyco clamp-type grommet to suit the mains cable I used (grommet #1210, SR-6P-4). There are plenty of similar types available. If you don't use a clamp-type grommet, then use an ordinary rubber grommet and a nylon cable clamp.

The mains socket requires holes to be drilled in the box to allow cables to the active, neutral and earth pins to pass through to the socket terminals. I first loosened the grub screws on the socket terminals, then positioned the socket where I wanted it and drilled pilot holes in the case through the terminals.

Now solder the electrolytic, C1, in place, taking care to orientate it correctly, followed by IC1 (get it the right way round) and RV1. The relay can be soldered to the board last of all.

Wires are run from the pc board to the mains circuitry, the pushbutton and the LED. Only ordinary light hookup wire (10 x 0.12 mm) need be used to connect up the LED and the pushbutton. The 2851 transformer primary wires are generally coloured red and black. It has three secondary wires, two the same colour. These are wired to the rectifier diodes D1-D4, as shown in the overlay/wiring diagram.

Wire the transformer primary very carefully. The brown active wire from the mains input cable goes to a terminal connector, where it joins the red wire from the transformer. Take a length of brown mains wire and connect it between this terminal connector and the COMMON relay terminal pad on the pc board. Another length of brown mains wire is run from the normally open (N/O) relay contact pad on the pc board to the active terminal of the mains output socket.

The blue neutral wire runs from the mains input cable direct to the neutral terminal on the mains output socket, along with the black wire from the transformer.

The green and yellow striped earth wire from the mains input cable goes direct to the earth terminal on the mains output socket. This wire should be longer than the other two from the mains input cable for safety reasons. Should the mains cable be accidentally pulled out from the case, the earth wire will be the last to break.

All finished? *Check everything thoroughly.*

That's all there is to it. Next thing to do is test and calibrate it.

Test and calibration

Set RV1 to the middle of its travel, then close the case so that you can't accidentally come in contact with the lethal mains voltage present.

Plug a bedside lamp into the output socket, plug the project into the mains and switch on. Nothing should happen. If all's well, press the pushbutton and the lamp should light. Now time how long it remains on (if it's 50 hours or more, you're going to need a *lot* of patience!).

If you have access to a frequency counter, then setting the timer is much easier. Just attach the frequency counter to pin 11 of IC2. The oscillator frequency is related to the timing period as follows:

$$\text{Frequency} = \frac{8192}{T}$$

where T is the desired period in seconds and the frequency is in Hertz.

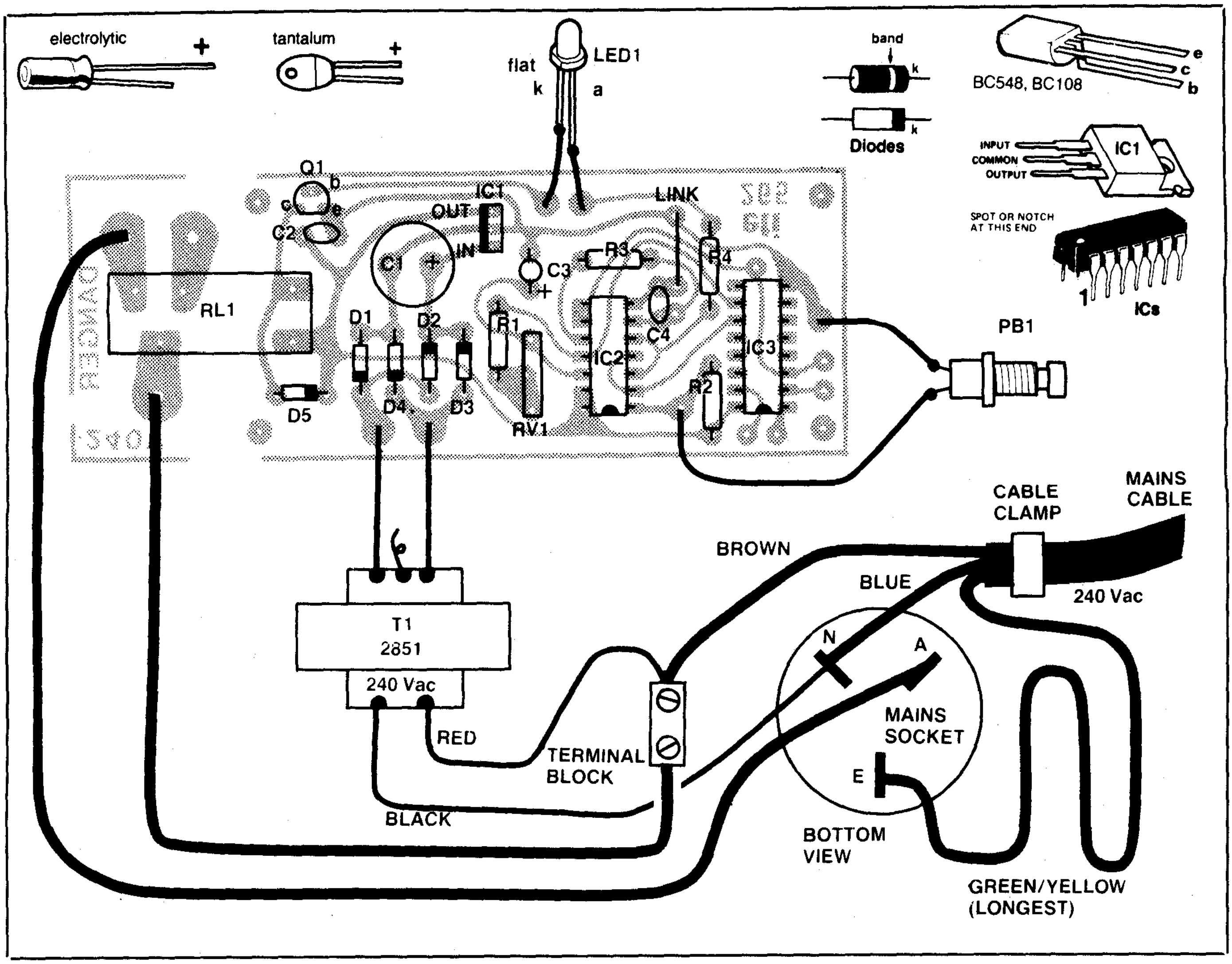
For a timing period of ten minutes, the frequency should be 13.65 Hz. For really long times, you're better off measuring the period of the oscillator output.

All you need do is to adjust RV1 for the correct frequency.

Binary periods

As mentioned earlier, the simple addition of a switch can give you binary (half, quarter, eighth) segments of the basic period. Details are shown in Figure 2.

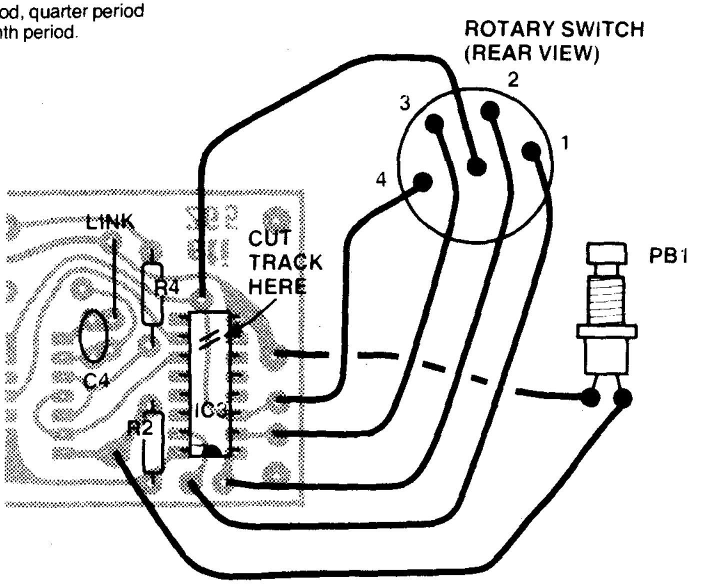
Cut the track that runs beneath the body of IC3, then wire a single-pole, four-position switch as shown. Position 4 gives you the full period. Position 3 gives the half period, position 2 one-quarter and position 1 gives one-eighth the period. ●



Timing Interval	C3	R1	RV1
1 minute	100n	47k	100k
5 minutes	100n	270k	500k
10 minutes	100n	470k	1M
20 minutes	1u	100k	220k
30 minutes	1u	150k	220k
45 minutes	1u	270k	500k
1 hour	1u	270k	500k
1½ hours	1u	390k	1M
2 hours	1u	680k	1M
4 hours	1u	1M2	2M2
10 hours	100u	27k	50k
20 hours	100u	56k	100k
50 hours	100u	150k	200k
100 hours	100u	270k	500k
200 hours	100u	560k	1M
400 hours	100u	1M2	2M

TABLE 1

Binary period switching. How to add a switch to get selections of full period, half period, quarter period and eighth period.



rower of the car he is effectively not given the option of inhibition! (Particularly useful if you are forced to leave your keys with an attendant in a car parking station.)

6). The power supply for the alarm circuitry is a particularly 'robust' design, in order to eliminate problems which can arise if the noisemaker draws large currents or develops strong interference signals. Hence the system can handle large and fast changes in supply without complaint. This allows the use of air horns and/or backup batteries should you wish. Performance is not compromised with a sick or flattish battery.

7). A dashboard failure warning indicator remoter is also incorporated. This is a circuit which emits a constant tone from the beeper if any crucial dash systems come on and remain on for more than 1.5 seconds. Hence, if an oil pressure warning light goes unnoticed, or the globe fails at a crucial point, a backup warning system is present.

If you ever have the fear that someone who has borrowed you car will not respond promptly to a glow in a warning panel, this is the system to relieve your nerves. Those who care to, can wire the 'low petrol' indicator to this, so that there is even more strong a warning just before you run out completely.

The remoter system waits about 20 seconds after the ignition is turned on and then starts to search the power supplies to the various connected dash indicators. If one goes active (either plus or ground as appropriate) and remains active for more than 1.5 seconds the beeper goes on for 15 seconds. Hence, in the case of the low petrol indicator, the sound only occurs when the lamp is pretty continuously on. If the alarm can protect the car when it is left alone, why shouldn't it do the same when it is being driven?

8). When installed as described, and with a main alarm noisemaker which is not accessible without violating the alarm (either a horn well concealed or a separate mechanism well away from prying hands) this alarm *meets all NRMA recommendations* for a vehicle alarm.

9). Finally, disarming occurs immediately when the ignition is applied, but immediate re-arming occurs if the ignition line does not remain on for at least three seconds. This means that a brief pulse may reset a trip but will leave the alarm armed. This can be handy in setting up, and makes it harder for inept fooling to bypass the system, or spurious glitches to cause disarming.

If the above points have not sold you on this project yet, you just don't love your car enough!

Construction

Before proceeding with details of the assembly and installation of this project let me say that a lot of care should be exercised here for three reasons: Firstly, the electronics will be stowed in some less accessible location in the vehicle making it tricky to access, even if you have the recommended connectors installed, and the sensors will be bonded solidly in various places around the body, so later corrections of errors will be painful. Secondly this is not a simple project, having two separate pc boards and a lot of interconnecting wiring in a small box, so mistakes are easier to make than normal. Lastly, sloppy or careless installation procedure can degrade the effectiveness of the whole project, possibly defeating its very purpose, so the moral is DON'T RUSH IT!

Two decisions are required before you leave the shop with the parts. The first is, namely, whether you intend to use the connectors in the cabling to permit quicker disconnection of the electronics from the fixed parts of the system. If you are dealing with a less accessible sort of car, or you cannot get a soldering iron to it easily, I *thoroughly recommend them.* Do not use the sort of connector that will work loose or corrode as these will surely cause more trouble than they save, but either go the 'whole hog', or wire directly. It will not affect operation — it is purely for your convenience. I will proceed assuming that you are going to use them, so just skip relevant parts if this is not the case.

Once you have have collected the electronic parts, unless you have bought a complete kit, you will have to go to a special supplier for the resonance microphones. **The 'Microphone pickup' item on p.81** discusses places you are likely to be able to get these, though you may have to order them. They may cost from $5 to $15 each, or thereabouts, depending where you go to get them. If you have a small car, two microphones will most likely be enough. If you have a large vehicle or you wish to have 'hair trigger' sensitivity, four will be required. It is perhaps wise to get four if they are not too expensive to save another trip later, but it is also quite acceptable to get two or even only one and add more later.

Armed with all the parts, the next step is to retire to the workroom and assemble the control box. The first phase consists of preparing the box. Preferably using the blank pc boards as templates, position the two sets of mounting holes to hold the boards. I placed the smaller board against the lid and the other on the bottom of the box such that they swing apart when the lid is removed, almost using the flying leads as hinges. This makes for a neat and compact arrangement when assembled.

Only one further hole is required, being the access point for all the wires to the various parts of the car. This should be about 10mm in diameter, and preferably fitted with a grommet.

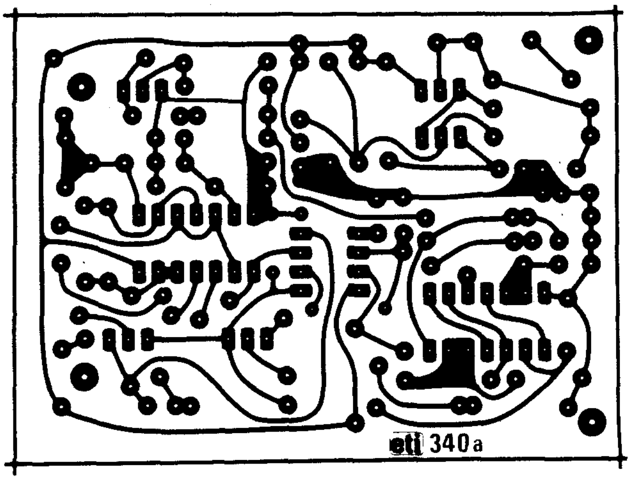
This done, assemble the boards according to the overlay diagrams. Remember, the resistors and some of the capacitors are the only parts which can be put in either way around — every other component will at least not function proplery and probably cause damage if inserted in any other way around than the correct way! It is best to insert and solder a few components at a time. Leave the ICs till last, but beyond this the order is irrelevant.

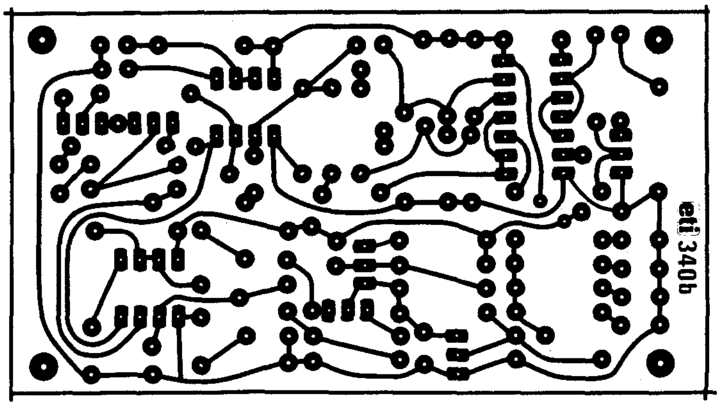
There are several links and flying leads involved, and it is perhaps best to do the links first, and flying leads last. You may like to insert each part in a logical sequence, following the circuit as you go to check the board. (The boards were fine when I last did it, but further checks cannot hurt!) Once soldered, trim the leads with side cutters, about 2 mm beyond the board surface.

If you are using connectors as recommended, leave about 250 mm of wire attached to each connection which is going to the outside of the box. Otherwise you had better leap ahead and figure out how long the wire is going to have to be!

The relay is best attached to the inside of the box with double-sided adhesive tape, such as obtained from hardware shops. This method of mounting is remarkably vibration-proof, and overcomes the fact that relays do not often have mounting holes. Gluing it to the case with silastic is also effective.

The cables running from the relay to out-





Printed circuit artwork. Reproduced full-size.

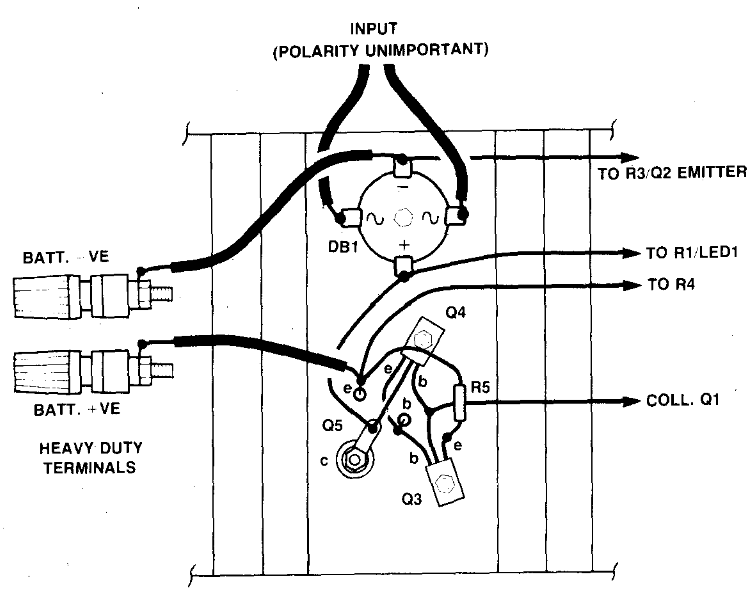


Figure 3. The diode bridge option costs a little more than the single diode but its advantage is that it can be connected in either way ignoring the polarity of the supply connections. It dissipates more power than the other options and has a voltage drop of about 1.7 V.

PARTS LIST — ETI-274

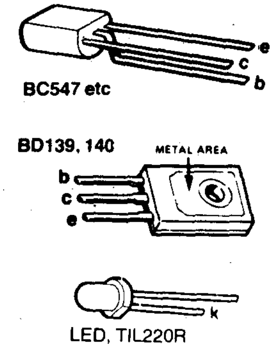
Resistors	all ½W, 5%
R1	18R
R2	560R
R3	10k
R4	1k8
R5	12-33R, see text
Semiconductors	
DB1	10-12 A bridge rectifier (PA40F or similar)
LED1	TIL220R red LED
Q1	BD140
Q2	BC547, BC107
Q3, Q4	BD139
Q5	2N3055

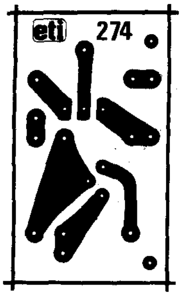
Miscellaneous

ETI-274 pc board; UB2 zippy box (if required) 60 x 113 x 196mm or similar; 100mm heatsink or larger; heavy duty terminals; heavy duty figure-8 cable (coded red/black); TO-220 transistor insulating and mounting hardware (two sets); TO3 mounting hardware; hookup wire — medium and heavy duty; nuts, bolts, etc.

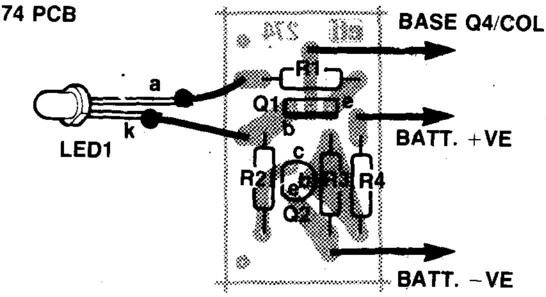
Price estimate $22-25

COMPONENT PINOUTS

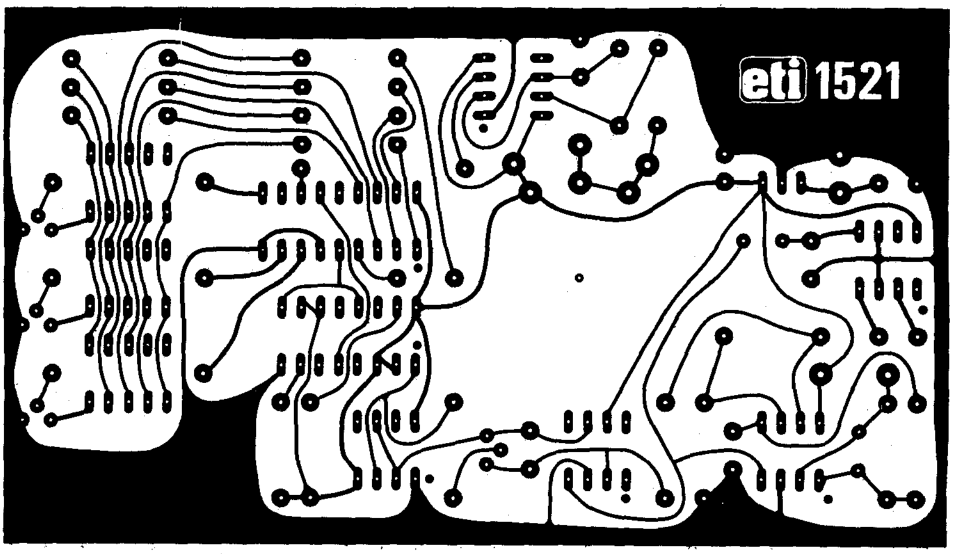




ETI-274 PCB



PCBs



Project 265

The 'power down' mains appliance timer

Have you ever turned on your electric radiator to warm a room in the morning and forgotten to turn it off on your way out? What about the patio light — ever turned that on and forgotten to turn it off until the next day? This project will not only solve those problems, but has many applications besides.

Geoff Nicholls

THIS IS a press-button mains appliance timer. You plug the project into a wall socket, plug your appliance into the project, then press the button to turn the appliance on. Some predetermined time later, the project will automatically *'power down'* (or turn off) your appliance.

No doubt you're familiar with those time switches installed in the stair wells of apartment buildings that control the stairway lights. You press the big button and the lights come on just long enough for you to *not quite* make it up the stairs! These devices employ a mechanical timer, their major problem being that, with use, the period decreases. In addition, you can't preset them to a convenient time over a wide range.

Many 'deluxe' electric heaters these days incorporate a timer of some sort so that the heater can be turned on for a preset period, then turn itself off. 'Super deluxe' models go so far as having a timer with digital display and programming facilities to turn it on and off whenever you like each day for a fortnight! That's probably going a bit far for many applications, though.

Getting 'closer to home', so to speak, take the case of an EPROM eraser. This basically comprises an ultraviolet lamp and a period timer. You bung your EPROMs under the lamp and turn on the timer. The timer then turns the lamp off the required period later (typically, 20 minutes).

In photographic work, film and print exposure times are often handled with a simple period timer. When making multiple exposures for comparisons, etc, binary-related exposure times are frequently used, e.g: print exposures of eight minutes, then four minutes, then two minutes, etc.

This versatile little timer will handle all the above applications and can be configured to suit a huge variety of other applications, probably only limited by your imagination.

This project can be set up for timing periods ranging from one minute up to at least 50 hours. Although I haven't tried it, it is certainly possible to extend the period to around 400 hours (16-17 days). Binary 'segments' of the basic period can be selected by the simple addition of a suitable switch. The project is low in cost and can be built into an appliance if you so wish.

Design

The unit is quite straightforward. Figure 1 shows a block diagram. It consists of an oscillator, a divider, a flip-flop, a relay driver and relay. The relay contacts are used to connect and disconnect the mains power from an attached appliance.

The oscillator output is divided down 8192 times. The divider's output drives the 'reset' input of the 'reset-set' (RS) flip-flop. The flip-flop has two outputs — A and B. In the initial, or reset, state, output A is high, resetting the divider in preparation for counting. Output B of the flip-flop is low and the relay is not operated.

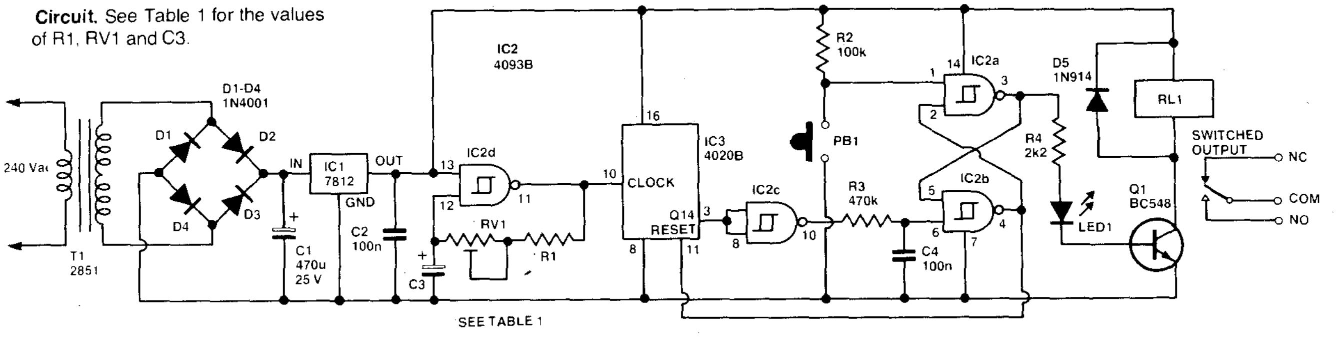
When the start button is pressed, the RS flip-flop is 'set'. Output B goes high, operating the relay and turning on the appliance connected via the relay. Output A goes low, enabling the divider to count down.

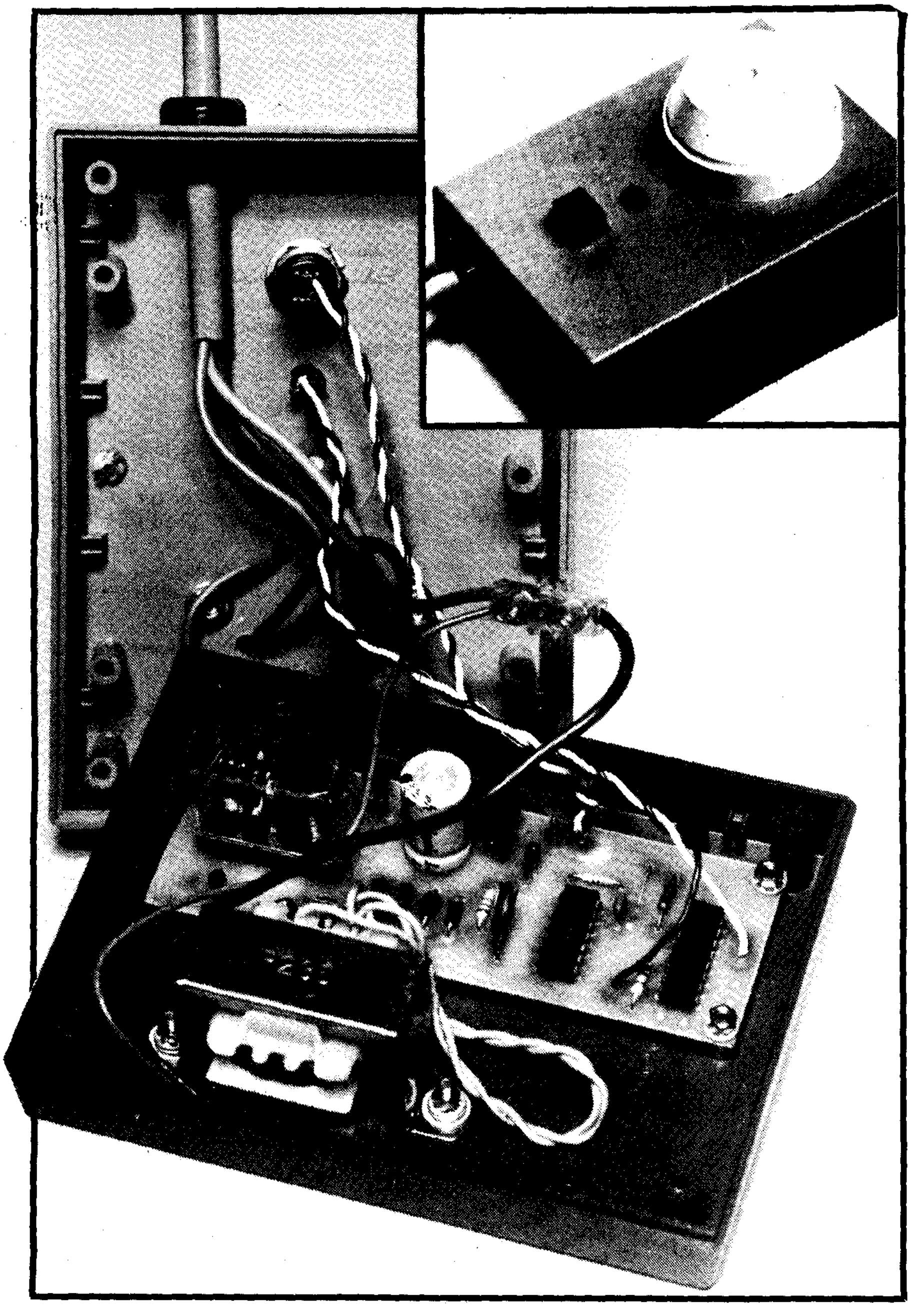
At the end of its count, the divider's output goes low, resetting the flip-flop. Output A goes high again, stopping the divider, and output B goes low. The relay then drops out, turning off the appliance connected via its contacts.

The oscillator's frequency will determine the basic period. Because the division ratio is so high, minor drifts or variations in the oscillator frequency will not materially affect the timing period, hence a simple oscillator can be used.

As the required timing period is determined by R1, RV1 and C3, the values you need for these components should be determined from Table 1 before commencing construction. It would be reasonable to expect a kit supplier *not* to include these in a kit, or to perhaps only include, say, a 1u RBLL or tantalum for C3 and perhaps a 1M trimpot, as these would cover a wide range of timing periods, leaving the choice of R1 to you.

Note that C3 should either be a tantalum type or single-ended 'low leakage' electrolytic for repeatable results. ▶


Circuit. See Table 1 for the values of R1, RV1 and C3.



▲

On the inside. Showing construction of the project and how I mounted it inside the Unibox case. Note that one of the internal pillars is cut down to provide clearance for the transformer. **Inset.** The completed project.

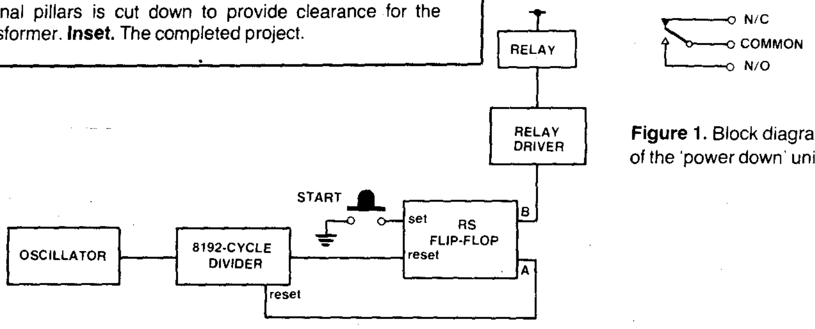


Figure 1. Block diagram of the 'power down' unit.

HOW IT WORKS — ETI-265

The overall design of the project is discussed in the text, so this shall largely be a blow-by-blow description of how it works. Let us start at the 'rear end' first.

Two gates from the 4093, IC2a and b, form the reset-set (RS) flip-flop. This is in the SET state when pin 3 of IC2 is high and pin 4 is low. It is in the RESET state when pin 4 is high and pin 3 low.

When the flip-flop is SET, Q1 is turned on as the high on pin 3 of IC2 biases on its base via R4 and LED1, which lights, indicating the unit is 'active'.

A momentary low on pin 1 of IC2 will SET the flip-flop, while a momentary low on pin 6 will RESET it.

On power-up, C4 will look like a short circuit and keep pin 6 of IC2 low long enough to RESET the flip-flop. Thus, pin 4 of IC2 will be high and reset IC3, a 4020B 14-stage binary counter with a division ratio of 8192:1.

Pin 3 of IC3 (the stage 14 output) will be low after the IC is reset and IC2 will invert this, pin 10 driving pin 6 high, allowing the flip-flop to be set when PB1 is pushed momentarily.

As soon as PB1 is pushed, the counter begins to count cycles of the Schmitt gate oscillator comprising IC2d, R1, RV1 and C3. The frequency of the oscillator is determined by RV1, R1 and C3 and the threshold voltages of the inputs of IC2d. (See 'Why some CMOS circuits don't work as you expect', ETI July 1983).

After 8192 cycles of the oscillator, pin 3 of IC3 goes high, thus resetting the flip-flop via IC2c. Pin 3 of IC2 will thus go low and the relay will drop out.

The oscillator works as follows: At power-up, pin 12 of IC2d will be low as C3 appears as a short circuit. Pin 13 will be high and thus pin 11 will be driven high. C3 will charge via R1 and RV1. When the voltage on C3 reaches the gate's upper threshold, pin 11 will go low and C3 begin to discharge via RV1 and R1. When the voltage on C3 falls to the gate's lower threshold, pin 11 will again go high and the cycle will be repeated.

The oscillator frequency is related to the timing interval (or period) as follows:

$$f_o = \frac{8192}{T}$$

where f_o is the oscillator frequency in Hertz, and T is the period in seconds. Expressing this in terms of the period:

$$T = \frac{8192}{f_o}$$

Table 1 allows you to set up the project for a particular timing interval. The range of adjustment provided should compensate for most of the variation in threshold voltages of the different manufacturers' 4093s. The time interval shown in the table refers to the prototype project. If you add the rotary switch to give four ranges, the longest interval will be as per the table, the next will be half that, then quarter that, etc.

The power supply is quite straightforward. Transformer T1 drops the mains voltage to 12.6 V RMS. This is rectified by a bridge diode comprising D1 to D4. Capacitor C1 is the rectifier reservoir. About 18 volts is developed across C1 and this is regulated to 12 V by a 7812 three-terminal regulator, IC1. Capacitor C2 ensures regulator stability.

Diode D5, across the relay, shorts the reverse-emf generated by the relay coil when Q1 switches off, preventing the high voltage generated from destroying Q1.

Construction

I built one prototype and mounted it in a plastic case, which you see in the photographs here, and another unit which I mounted inside an appliance (ask no questions and . . .)

I used an all-plastic Unibox (P/N144) measuring 135 mm long by 100 mm wide by 50 mm deep. (Magraths in Melbourne are a major supplier of these.) It has ample room inside. You could use a UB-1 zippy box (50 x 90 x 150 mm), but an all-plastic case is recommended for safety's sake. Jaycar stock a range of smart, all-plastic (ABS) cases in various colours. The HB6150, 1, 2, 3 series (orange, grey, blue, black) would suit.

First thing to do is determine the mounting positions of the printed circuit board and transformer. Lay the unassembled pc board and the transformer in the base of whatever box you're using and mark the positions of the mounting holes.

Then mark out suitable positions for the mains cable entry, the pushbutton, the LED and the mains socket. For the mains cable entry, I used a Heyco clamp-type grommet to suit the mains cable I used (grommet #1210, SR-6P-4). There are plenty of similar types available. If you don't use a clamp-type grommet, then use an ordinary rubber grommet and a nylon cable clamp.

The mains socket requires holes to be drilled in the box to allow cables to the active, neutral and earth pins to pass through to the socket terminals. I first loosened the grub screws on the socket terminals, then positioned the socket where I wanted it and drilled pilot holes in the case through the terminals.

After drilling all the holes, mount the transformer, output socket, LED and pushbutton, but not the pc board — you've got to assemble that yet! To mount the transformer, I used insulating washers from a TO-3 power transistor mounting kit. An alternative is to use nylon bolts. The latter were used to mount the pc board.

Note that, if you wish, the section of the board on which the relay mounts can be severed from the rest of the board, allowing the relay to be mounted away from the main portion of the electronics.

Assembly of the board is pretty straightforward. Start with the smaller components. Solder all the resistors in place, then the five diodes, C2, C3 and C4. Watch the orientation of C3 and the diodes. Solder a link of tinned copper wire in the position shown, between C4 and R4. Now you can solder IC2 and IC3 in place.

These are CMOS ICs. Use an iron with an earthed tip and only handle the ICs with your thumb and forefinger gripping the ends of the package. Avoid touching the pins. When you have each in place, solder pins 7 and 14 of IC2 first and pins 8 and 16 of IC3 first, before going on to solder the other pins. If you wish, IC sockets may be used without affecting operation of the project.

Next solder Q1 in place. Its orientation can be ascertained from the pinout diagram and the component overlay.

Now solder the electrolytic, C1, in place, taking care to orientate it correctly, followed by IC1 (get it the right way round) and RV1. The relay can be soldered to the board last of all.

Wires are run from the pc board to the mains circuitry, the pushbutton and the LED. Only ordinary light hookup wire (10 x 0.12 mm) need be used to connect up the LED and the pushbutton. The 2851 transformer primary wires are generally coloured red and black. It has three secondary wires, two the same colour. These are wired to the rectifier diodes D1-D4, as shown in the overlay/wiring diagram.

Wire the transformer primary very carefully. The brown active wire from the mains input cable goes to a terminal connector, where it joins the red wire from the transformer. Take a length of brown mains wire and connect it between this terminal connector and the COMMON relay terminal pad on the pc board. Another length of brown mains wire is run from the normally open (N/O) relay contact pad on the pc board to the active terminal of the mains output socket.

The blue neutral wire runs from the mains input cable direct to the neutral terminal on the mains output socket, along with the black wire from the transformer.

The green and yellow striped earth wire from the mains input cable goes direct to the earth terminal on the mains output socket. This wire should be longer than the other two from the mains input cable for safety reasons. Should the mains cable be accidentally pulled out from the case, the earth wire will be the last to break.

All finished? *Check everything thoroughly.*

That's all there is to it. Next thing to do is test and calibrate it.

Test and calibration

Set RV1 to the middle of its travel, then close the case so that you can't accidentally come in contact with the lethal mains voltage present.

Plug a bedside lamp into the output socket, plug the project into the mains and switch on. Nothing should happen. If all's well, press the pushbutton and the lamp should light. Now time how long it remains on (if it's 50 hours or more, you're going to need a *lot* of patience!).

If you have access to a frequency counter, then setting the timer is much easier. Just attach the frequency counter to pin 11 of IC2. The oscillator frequency is related to the timing period as follows:

$$\text{Frequency} = \frac{8192}{T}$$

where T is the desired period in seconds and the frequency is in Hertz.

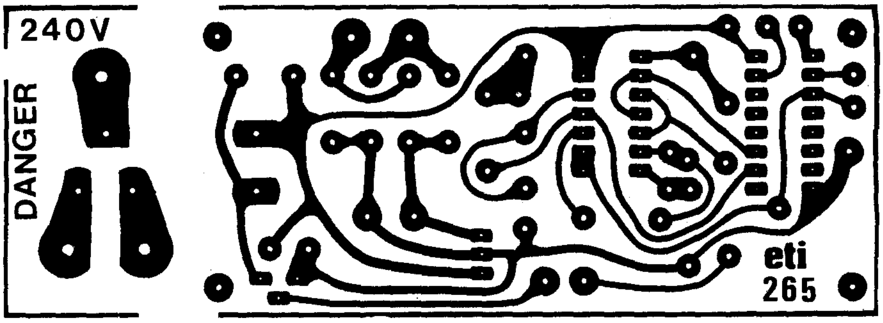
For a timing period of ten minutes, the frequency should be 13.65 Hz. For really long times, you're better off measuring the period of the oscillator output.

All you need do is to adjust RV1 for the correct frequency.

Binary periods

As mentioned earlier, the simple addition of a switch can give you binary (half, quarter, eighth) segments of the basic period. Details are shown in Figure 2.

Cut the track that runs beneath the body of IC3, then wire a single-pole, four-position switch as shown. Position 4 gives you the full period. Position 3 gives the half period, position 2 one-quarter and position 1 gives one-eighth the period. ●

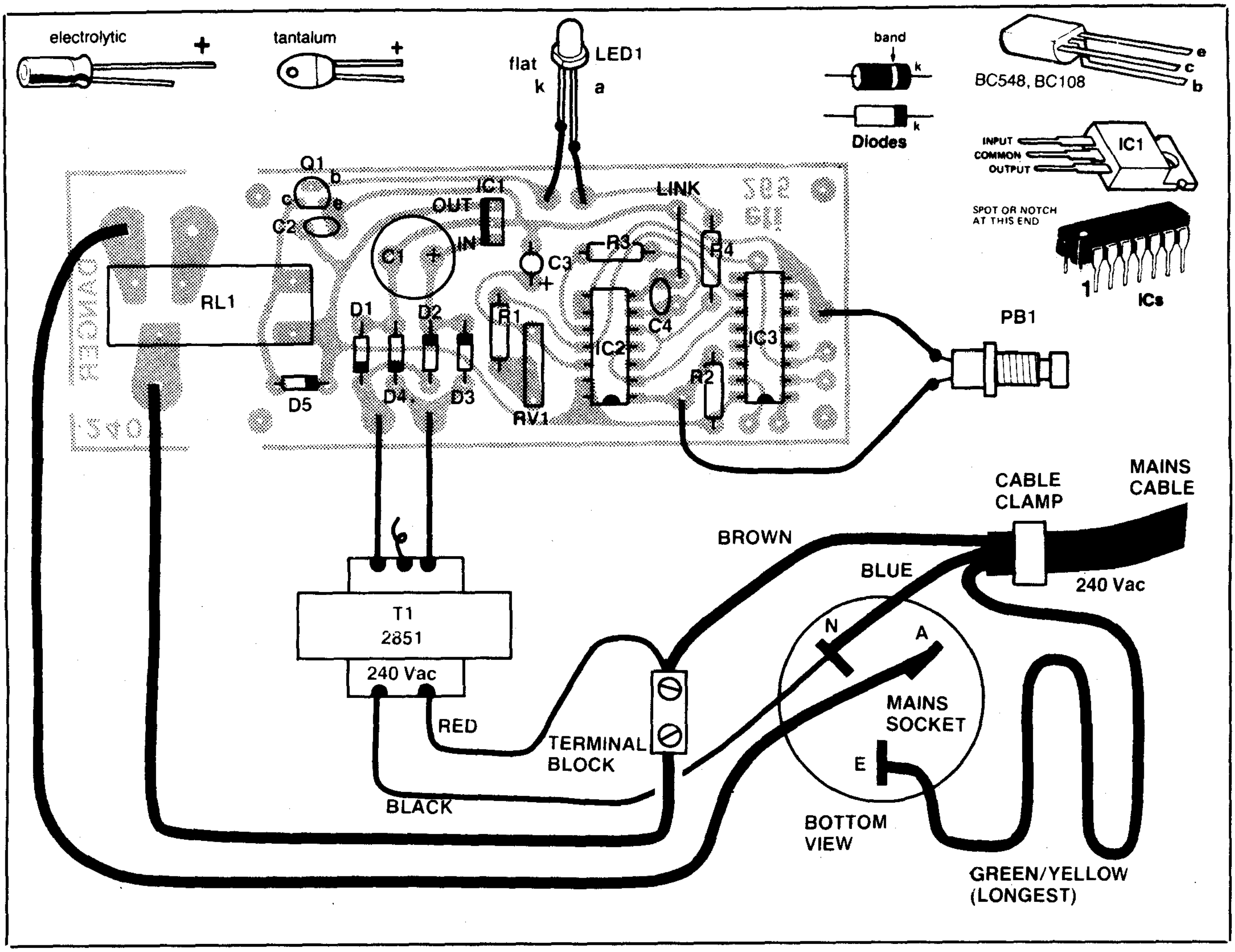


PARTS LIST — ETI-265

Resistors	all ¼ W, 5% unless noted
R1	47k
R2	100k
R3	470k
R4	2k2
Capacitors	
C1	470u/25 V single-ended electro.
C2,C4	100n greencap
C3	1u/16 V tantalum
Semiconductors	
D1-D4	1N4001, 1N4002 or similar
D5	1N914, 1N4148
IC1	7812
IC2	4093B
IC3	4020B
LED1	TIL220R red LED
Q1	BC548
Miscellaneous	
PB1	momentary action pushbutton, large (e.g: D.S.E. no. S-1199 or similar)
RL1	pc mount relay, 12 V coil SPDT/5 A contacts (e.g: D.S.E. S-7125, or similar)
T1	2851 transformer, 12.6 V CT @ 150 mA

ETI-265 pc board; case to suit (e.g: Unibox P/N 144, 100 x 135 x 50 mm, or similar); LED mount; 240 V wall socket; mains cable plug, cable and clamp; wire, etc.

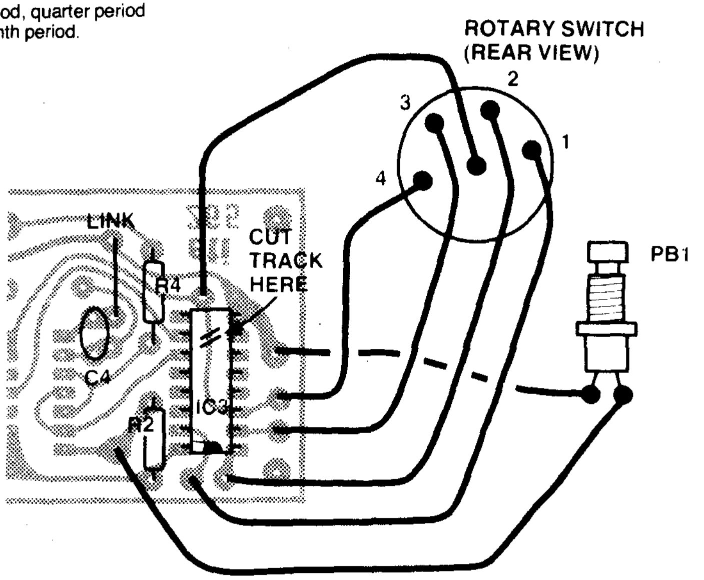
Price estimate $32-$37

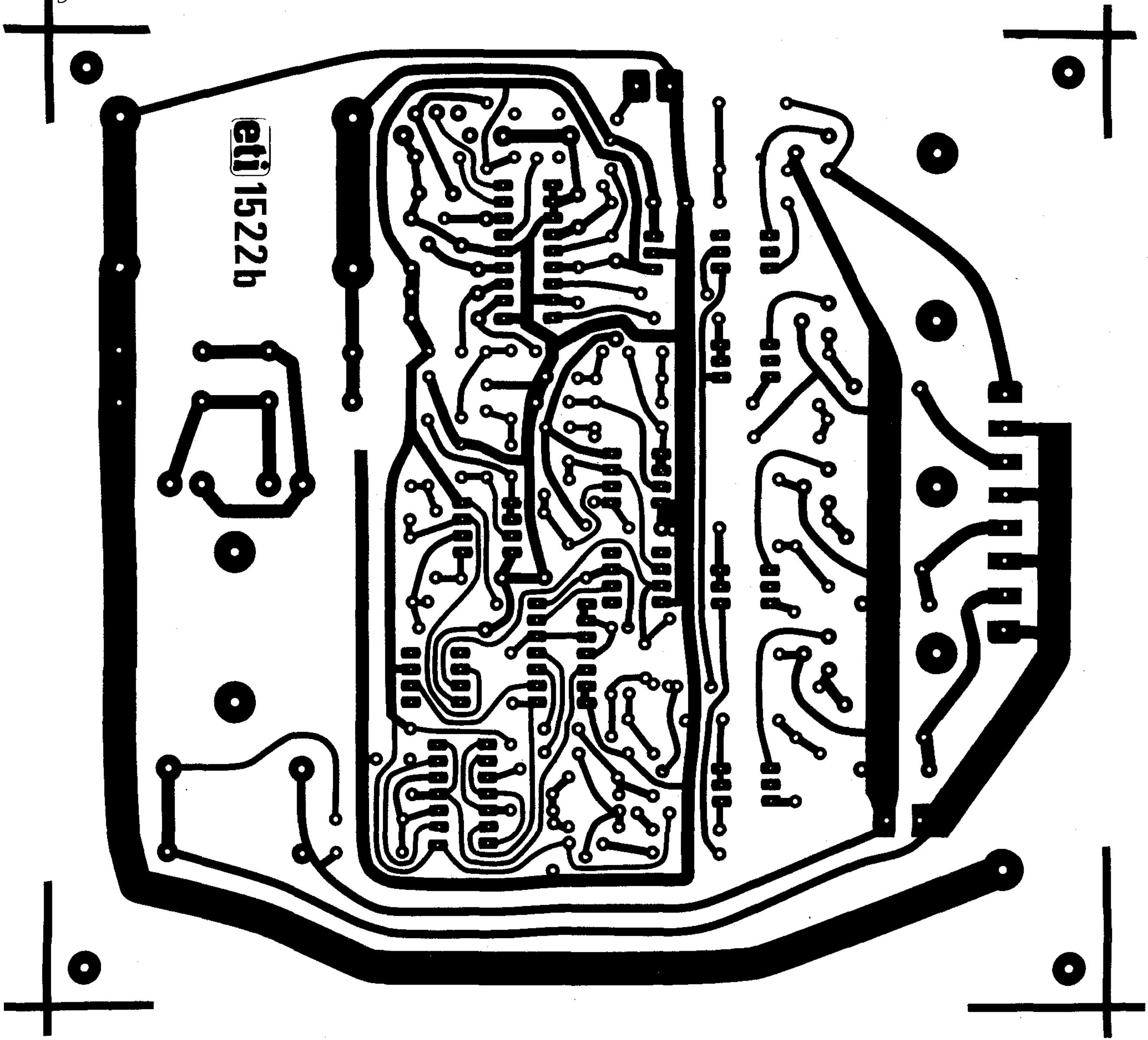


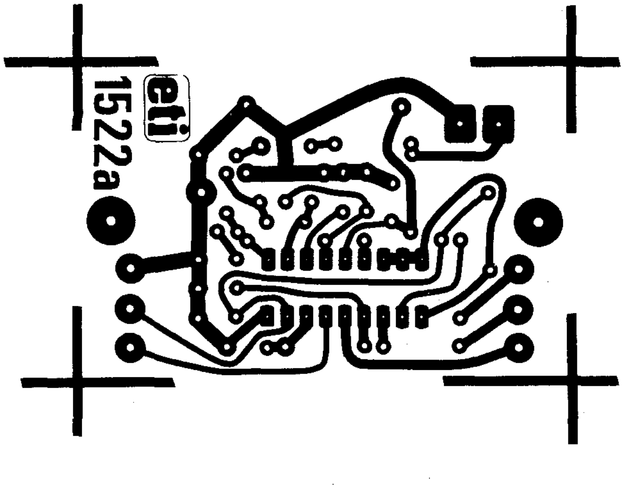
Timing Interval	C3	R1	RV1
1 minute	100n	47k	100k
5 minutes	100n	270k	500k
10 minutes	100n	470k	1M
20 minutes	1u	100k	220k
30 minutes	1u	150k	220k
45 minutes	1u	270k	500k
1 hour	1u	270k	500k
1½ hours	1u	390k	1M
2 hours	1u	680k	1M
4 hours	1u	1M2	2M2
10 hours	100u	27k	50k
20 hours	100u	56k	100k
50 hours	100u	150k	200k
100 hours	100u	270k	500k
200 hours	100u	560k	1M
400 hours	100u	1M2	2M

TABLE 1

Binary period switching. How to add a switch to get selections of full period, half period, quarter period and eighth period.







RADIO INTERFERENCE?

As the 'carrier' for this system is on 455 kHz, the standard intermediate frequency (I.F.) for broadcast receivers, readers may be worried that some interference may be caused to radios in the room or house where this system is installed. Don't worry. We tried putting a sensitive portable transistor radio right next to the switch plate and the twin-wire cable. *Very* weak heterodynes ('whistles') can be heard on weak carriers between stations, but not on signals which can be clearly heard, though weak. On local stations there's *no effect whatever*. Once the receiver is moved a few centimetres away, no heterodynes at all can be detected.

The twin-wire cable between the encoder/transmitter and the receiver/triac driver acts as a low impedance transmission line, so radiation from it is very low in any case. The transmitter in the LM1871 is operated at a very low level, deliberately, because high levels are unnecessary, greatly reducing the possibility of interference — as our test showed.

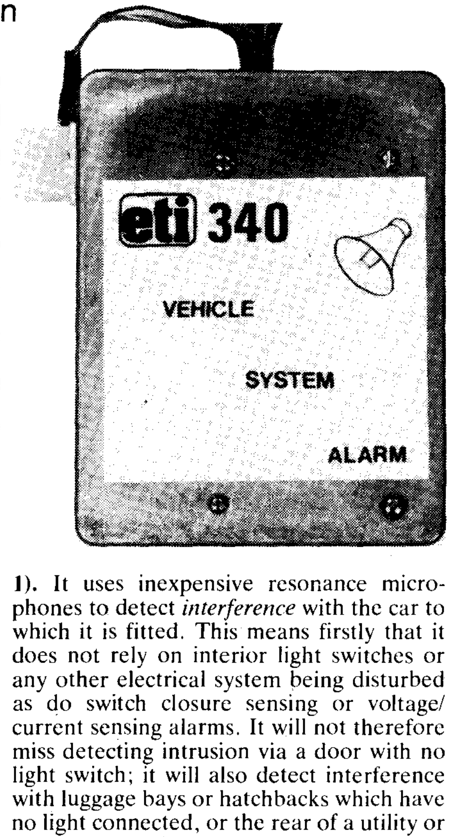
As the line between the encoder/transmitter and receiver/triac driver boards is isolated from the mains by the power supply, mains-borne interference should not occur.

●

Versatile vehicle security alarm provides full protection for almost any vehicle

Jonathan Scott

This unit will protect your valuable vehicle from virtually any sort of interference — from hub-cap stealing to being towed away! It does not rely on voltage or current sensing to trip the alarm, but 'resonance microphones'. It can also protect 'perimeter accessories' like driving lights and racks. The project meets the major requirements of car alarms set down by the National Roads and Motorists Association NRMA).



CAR BURGLAR ALARMS are plentiful on the shelves of electronic and automotive stores, and designs for build-it-yourself ones abound in the archives of every electronics magazine. In fact the range is so perplexing that choosing one becomes as involved a process as buying the vehicle in the first place! Which thought brings me to an interesting question — what does one unit, a car or an alarm, or any item, have over its apparent peers? Often it is merely that some recent technical development has become available at a reasonable price. A new car may come today with a turbo-charging system, electronic braking or gear control, or intelligent suspension. Perhaps a new product has just brought together a number of discreetly-developed good design ideas, much as today's 'food processors' incorporate the functions of blenders, ordinary mixers and mincers in one appliance with reliable electronic speed control. Finally, the improvement in a product may merely be the sum total of a lot of refining effort, as is the case in computers where the operating systems are more friendly and easier to use every time a new model comes out, or in a typewriter, which appears the same as ever, but feels a little better in the push of a key, and makes a little less noise than last year's model.

ETI's new car burglar alarm which we call a Vehicle Security Alarm, for the same reasons that food processors changed their names from 'mixmasters', has some of each of the three plusses above. It uses new alarm technology which we have not seen in a home construction design before, has certain additional incorporations beyond the functions of straight burglar protection, and has some facilities to make its use convenient and foolproof.

What are the features and advantages of this new design?

1). It uses inexpensive resonance microphones to detect *interference* with the car to which it is fitted. This means firstly that it does not rely on interior light switches or any other electrical system being disturbed as do switch closure sensing or voltage/current sensing alarms. It will not therefore miss detecting intrusion via a door with no light switch; it will also detect interference with luggage bays or hatchbacks which have no light connected, or the rear of a utility or panel van which is not enclosed. It can protect a convertible or targa body vehicle, or a truck with an open load area. Voltage and current types cannot satisfactorily do this.

Secondly, it will detect a sideswipe or minor impact such as so often occurs while your car is in the car park — the kind of dent which is not worth claiming on the insurance but which surely reduces the value of a vehicle and ruins its appearance. Even children interfering with the mirrors or similar can be detected, as actual inva-

THE NRMA'S TEN COMMANDMENTS FOR VEHICLE PROTECTION

In the February 1983 issue of *Open Road,* the NRMA's journal for members, the Association reported on tests they had carried out on some 24 car alarms, 14 fitted by suppliers or agents and 10 bought in kit form. As the report said, "The extensive tests and checks revealed deficiencies in design or performance of all 24 alarms, though most of them could have been improved by minor modifications or — in the case of the supplier-fitted types — by more care in fitting."

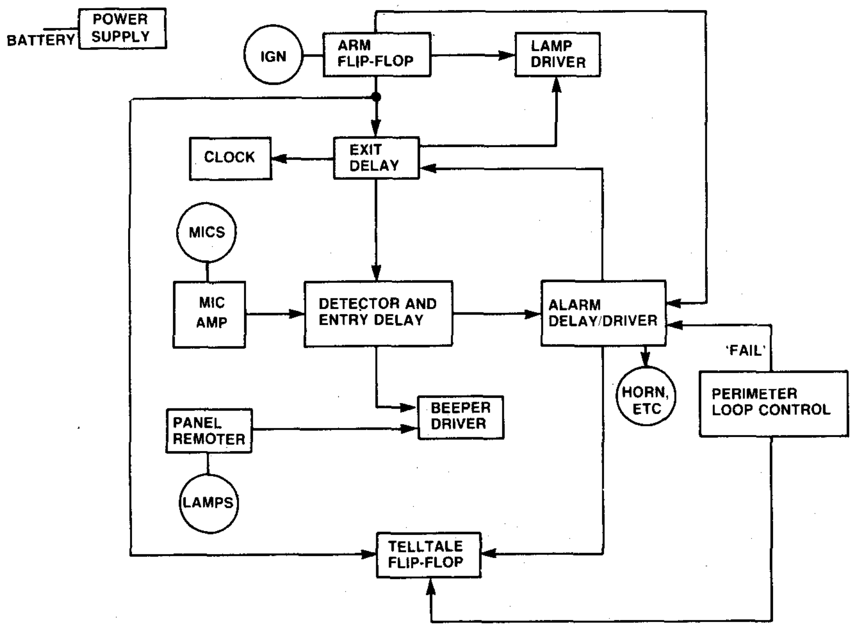
The report identified the key areas that need protection in a car. "When it comes to theft risk, 10 vulnerable points on a car are front doors, rear doors, bonnet, boot, ignition, accessories, wheels, glass and accessibility to towing and jacking," the report stated. It went on to say, "None of the alarms attempted to cover all 10 points, and some were unsuccessful in attempts to cover particular points because of poor components or poor fitting."

Based on police figures for reported thefts, you have a 1-in-50 chance of your car being stolen; if your car is a model in demand, the odds shorten considerably. The NRMA say that the fitting of a car alarm can reduce the risk of theft by deterring at least joy riders and petty thieves. Even a professional thief, seeing that the vehicle has a car alarm fitted, may move on in search of an easier mark.

The NRMA gives "10 Commandments" for buying protection:

1. The alarm should protect all the doors, bonnet and boot, at least.
2. It should operate instantly when the bonnet or boot is opened, or when the bonnet lock is released.
3. Air horns or a siren should be used, rather than the car's horn.
4. The alarm should be set from inside the vehicle, not by a key or other device from the outside.
5. Entry delay should be no more than five seconds.
6. The alarm should cut out the ignition system.
7. If the alarm obtains its power from the battery, wiring should be direct and should be positioned so that it cannot be reached from under the vehicle.
8. Horns or sirens and their wiring should be placed so they cannot be tampered with from behind the grille or from under the car.
9. The alarm duration should be about two minutes, with automatic cutout and reset.
10. Window stickers should indicate that the car is carrying an alarm system, but not the make and type.

It was this report that set in motion our quest for a car alarm project that would be versatile yet afford complete protection. We think this project can be installed so as to obey the Ten Commandments; although we disagree with No. 6. Artwork to comply with No. 10 is reproduced elsewhere in the article.



VSA BLOCK DIAGRAM

sion of the body or cabin is not necessary for detection to occur. Neither is the electronic state of the vehicle able to upset the alarm, thus eliminating false alarms due to random battery voltage variations or dash clocks drawing irregular currents.

2). The alarm is of the sensible three-delay design, but incorporates a failsafe against you forgetting it or missing one delay. By three-delay, I mean that it allows a period of time between activation and arming to allow you time to leave; a period of time between detecting possibly legal entry and sounding the alarm; and a period of time for which the alarm is sounded before resetting. Each of these is separately variable. Once activated, the warning lamp illuminates constantly; when the exit delay is over, the lamp flashes, indicating full arming. Once fully armed, a possibly legal entry/interference detection starts the second, or entry, delay. During this delay a beeping sound is emitted to quietly warn you that you have tripped the alarm (and the *thief* also that *he* has tripped it). This helps to prevent false and embarrassing blasts of the alarm noisemaker.

The final delay shuts off the alarm after a period of time, in accordance with the law of the land, not to mention the law of flat batteries! Once shut off, the system commences re-arming. This relatively 'friendly' arrangment permits full protection with minimum chance of false alarm and *no* drilling, etc of the body for installation of external switches or locks.

3). Immediate-trip perimeter inputs are provided. This facility, often missing from three-delay designs, allows the fitting of a mercury or tilt switch to the part of the car containing the battery. Without this it is relatively easy to disconnect the battery lead, killing the alarm, within the entry delay time period.

With such a mechanism connected an attempt to kill the power does at least attract a lot of attention.

In addition, connections to external driving or fog lights can be monitored and the alarm will go immediately if their earth connections are broken. These immediate loops (one normally closed, the other normally open) need not be used if not required, and if one is broken or shorted at arming time the remaining protection functions are not impaired. In addition, warning is given of a failed loop circuit, as indicated below.

4). While the state of the alarm (arming, armed, tripped, etc) is always made clear by the main lamp and the beeper, other statuses are reported by a second indicator, a 'tell-tale' LED. This glows to indicate that the alarm has gone off in your absence, and if it remains glowing after turning off the alarm by turning on the ignition, this indicates a failure in the loop circuits. Hence you are always informed as to what is going on inside the alarm circuits. The automatic rearming does not cancel the Tell-tale.

5). Alarms with automatic arming when the ignition is removed are a nuisance; conversely, an alarm which requires you to press a button to initiate arming are too open to forgetfulness. Having a concealed toggle or keyswitch is also inconvenient.

This alarm overcomes these problems by employing the usual illuminated pressbutton in an unusual mode. Turning off the ignition commences the arming cycle, *unless* the button is simultaneously pressed. Hence, normal behaviour automatically arms the system, overcoming forgetfulness, while the arming is simply overriden should you desire it by use of the button and the ignition key at once. Thus, disarming for service, etc, is facilitated. In addition, if the technique is deliberately not told to a bor-▶

PARTS LIST — ETI-340

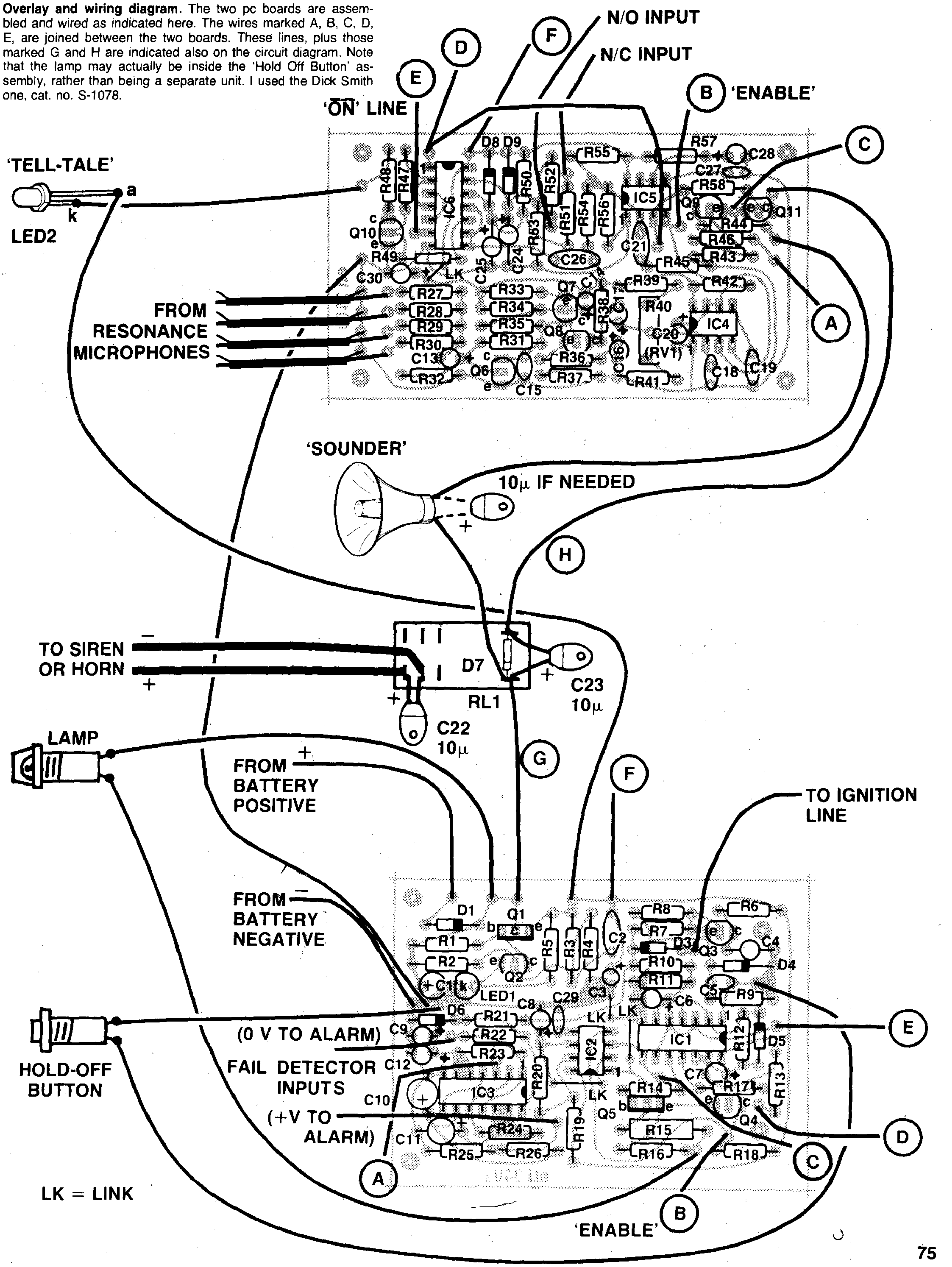
Resistors	all ¼W, 5% unless noted
R1, R38	560R
R2	33k
R3, 5, 6, 8	1k
R4	680R
R7	5k6
R9, R32	330k
R10, 11, 20, 34, 50, 53, 55, 56	100k
R12	1M
R13, 17, 27-30, 51, 52	10k
R14, 22, 25, 58	1k5
R15	56R, 1W
R16	390R
R18	1k8
R19, 47, 49	4k7
R21, 48	270R
R23, 26	150k
R24	390k
R31	680k
R33	2k2
R35	68k
R36	100R
R37	1k2
R39, R41	6k8
R42	180k
R43, 45, 46, 54	3k9
R44	180R (see text)
R57	1M2
RV1(R40)	10k vert. mount trimpot
Capacitors	
C1	47µ/16 V pc mount tant. or LL electro.
C6, 14, 24, 25	100n/6 V tant.
C3, 8, 9, 10, 12, 13, 16, 17, 22, 23, 30	10µ/6 V tant.
C4	150n ceramic or greencap
C7, 11, 20, 28	47µ/6 V tant. or LL electro
C5, C15	1n ceramic or greencap
C18, 19, 27, 29	10n ceramic
C2, 21, C26	100n ceramic or greencap
Semiconductors	
D1, D3	EM401, 1N4001, 1N4002 etc.
D2(LED1)	TIL220R red LED
D4, 5, 7, 8, 9	1N914, 1N4148, 1N4001, 1N4002 etc.
D6	10 V/400 mW or 1 W zener
D10(LED2)	TIL220G green LED or colour choice
IC1, 3, 6	4001
IC2, 4, 5	555
Q1	BD139
Q2, 6, 8	BC549
Q3, 4, 10	BC547/8/9
Q5	BC639 or BD139
Q7	BC559
Q9, 11	BC547
Miscellaneous	
PB1	Push-to-make switch. This can have the lamp indicator mounted internally if you wish (6 V globe).

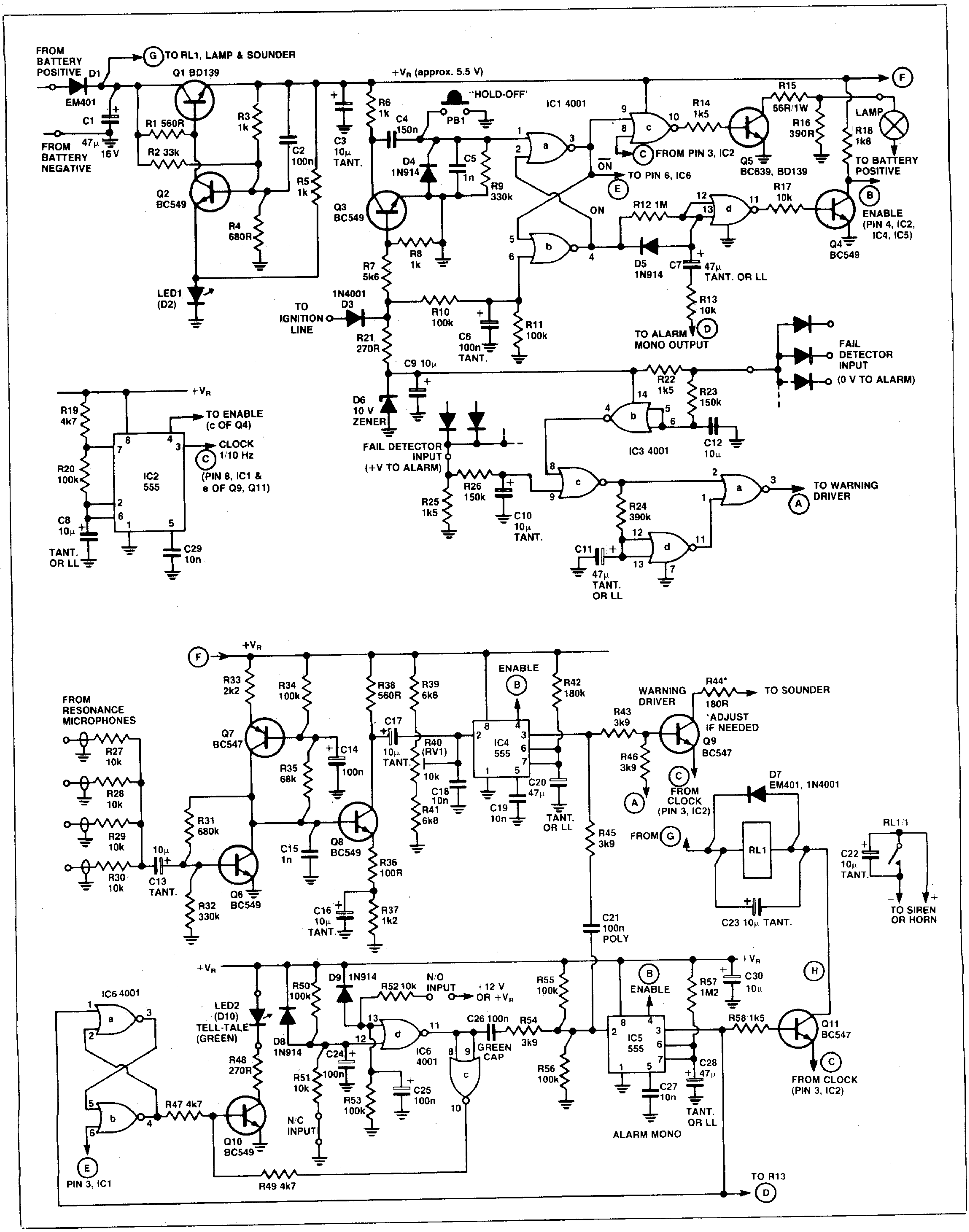
ETI-340a and b pc boards; RL1 — relay with 12 V coil and contacts rated to suit horn or siren used; LED mounting bezel for Tell-Tale LED; Panel mount lamp, 6 V globe (but see PB1); Piezoelectric 'sounder' or buzzer (e.g: Altronics S5062 or D.S.E. L-7009, etc.); Up to four resonance microphones (see text); Mercury switch (e.g: glass type, Altronics S3070); Multiway male and female automotive connector — 6-pin and 9-pin or contact sets to suit (e.g: Tandy 274-226/274-236, 274-229/274-239 or similar); In-line RCA male and female connectors — number to suit number of microphones; Superglue or double-sided sticky pads; 5-minute epoxy; 4BA nuts, bolts and washers to suit; 12 mm spacers, Diecast box — 120 x 95 x 55 mm or similar; Scotchcal labels; Cable ties or insulation *tape* (ties preferred); Hookup wire — various colours, some 10 x 0.2 mm, some heavy duty 24 x 0.2 mm; Additional siren or horn, if needed.

Price estimate: $65-$80

(depending on optional parts)

Overlay and wiring diagram. The two pc boards are assembled and wired as indicated here. The wires marked A, B, C, D, E, are joined between the two boards. These lines, plus those marked G and H are indicated also on the circuit diagram. Note that the lamp may actually be inside the 'Hold Off Button' assembly, rather than being a separate unit. I used the Dick Smith one, cat. no. S-1078.




FROM BATTERY POSITIVE
D1
EM401
G TO RL1, LAMP & SOUNDER
Q1 BD139
+VR (approx. 5.5 V)
C1 47µ 16 V
FROM BATTERY NEGATIVE
R1 560R
R2 33k
R3 1k
C2 100n
R5 1k
Q2 BC549
R4 680R
LED1 (D2)
C3 10µ TANT.
R6 1k
C4 150n
"HOLD-OFF"
PB1
D4 1N914
C5 1n
R9 330k
Q3 BC549
R8 1k
R7 5k6
TO IGNITION LINE
1N4001 D3
R10 100k
C6 100n TANT.
R11 100k
R21 270R
C9 10µ
D6 10 V ZENER
IC1 4001
a
b
c
d
ON
ON
C FROM PIN 3, IC2
E TO PIN 6, IC6
R12 1M
D5 1N914
C7 47µ TANT. OR LL
R13 10k
TO ALARM MONO OUTPUT D
R14 1k5
Q5 BC639, BD139
R15 56R/1W
R16 390R
LAMP
R18 1k8
TO BATTERY POSITIVE
F
R17 10k
Q4 BC549
B ENABLE (PIN 4, IC2, IC4, IC5)
FAIL DETECTOR INPUT (0 V TO ALARM)
R22 1k5
R23 150k
C12 10µ
IC3 4001
FAIL DETECTOR INPUT (+V TO ALARM)
R25 1k5
R26 150k
C10 10µ TANT.
R24 390k
C11 47µ TANT. OR LL
TO WARNING DRIVER A
R19 4k7
R20 100k
C8 10µ TANT. OR LL
IC2 555
C29 10n
+VR
TO ENABLE (c OF Q4)
C CLOCK 1/10 Hz (PIN 8, IC1 & e OF Q9, Q11)
F +VR
FROM RESONANCE MICROPHONES
R27 10k
R28 10k
R29 10k
R30 10k
C13 10µ TANT.
R33 2k2
R34 100k
Q7 BC547
C14 100n
R35 68k
R31 680k
Q6 BC549
R32 330k
C15 1n
Q8 BC549
R38 560R
R36 100R
C16 10µ TANT.
R37 1k2
C17 10µ TANT.
R39 6k8
R40 (RV1) 10k
R41 6k8
C18 10n
ENABLE B
IC4 555
C19 10n
C20 47µ TANT. OR LL
R42 180k
WARNING DRIVER
R43 3k9
R46 3k9
A
R44* 180R *ADJUST IF NEEDED
TO SOUNDER
Q9 BC547
C FROM CLOCK (PIN 3, IC2)
D7 EM401, 1N4001
FROM G
RL1
C23 10µ TANT.
RL1/1
C22 10µ TANT.
TO SIREN OR HORN
R45 3k9
C21 100n POLY
H
IC6 4001
LED2 (D10) TELL-TALE (GREEN)
R48 270R
D8 1N914
R50 100k
D9 1N914
R52 10k
N/O INPUT +12 V OR +VR
C24 100n
R51 10k
N/C INPUT
R53 100k
C25 100n
C26 100n
GREEN CAP
R54 3k9
R55 100k
R56 100k
ENABLE B
IC5 555
C27 10n
ALARM MONO
R57 1M2
C30 10µ
C28 47µ TANT. OR LL
R58 1k5
Q11 BC547
C FROM CLOCK (PIN 3, IC2)
R47 4k7
Q10 BC549
R49 4k7
E PIN 3, IC1
TO R13 D

HOW IT WORKS — ETI-340

Though an apparently complex circuit, it can be broken down into 12 simple blocks. Referring to the block diagram first, these are Power Supply, Clock, Arming Flip-Flop, Lamp Driver, Exit Delay, Mic. Amplifier, Detector/Entry Delay, Alarm Delay/Driver, Panel Remoter, Beeper Driver, Perimeter Loop Control and Tell-tale Flip-flop. Referring now to both the circuit and the block diagram, we can discuss the function of each part discreetly.

The power supply provides approximately 5.5 volts for the electronics. Using so low a rail voltage permits the regulator to work with a large overhead, giving increased immunity to fluctuations in the battery voltage as are commonly encountered in the automotive environment. The supply consists of D1, the reverse polarity protection diode, which also serves to isolate C1 in the event that a spike on the supply drops the supply voltage below about 9 V. The supply reference consists of LED1 plus Q1 and Q2, the series pass and comparator elements, respectively, in a conventional series pass feedback regulator. Resistor R2 provides feedforward to give nearly perfect line regulation despite the low loop gain. Capacitors C2 and C3 ensure good ac load regulation (dc load regulation is not important here).

The first two gates in IC1 form the 'ARM' RS flip-flop. Initially, consider that the ignition line is high, that is about +12 volts. R10 limits the current delivered into the protection diodes on the gate input, which is held near the 5.5 volt supply. Hence the gate output (ON) is low, and the system is disarmed. Because R9 holds the other gate's second input low also, its output ($\overline{\text{ON}}$) is high. Q3 is held on by current through R7. When the ignition line goes low (the car's ignition is turned off) the input of the first gate is pulled low by R11.

Two responses are possible, depending upon whether the pushbutton, PB1, is pressed or not.

If the button is not pressed, Q3 turns off and delivers a momentary positive-going pulse to the second input of the second gate, toggling the RS flip-flop. In this condition, which corresponds to the arming state of the alarm, the output of the second gate ($\overline{\text{ON}}$) goes low and is held low, while the other output is sent, and held, high.

If the button is pressed, the brief pulse is shorted out, and no change in the state of the flip-flop occurs. Hence, whenever a negative-going edge occurs on the ignition line (the ignition is turned off) the button is read to see if arming is required, the default being to arm.

Whenever the ignition line goes high, the level is conveyed to the first input of the first gate, resetting the flip-flop, irrespective of the button. The flip flop provides both the ON signal and its complement.

The Exit Delay is provided by R12, D5, C7 and the third gate in IC1. When the ON line goes high, C7 proceeds to charge toward the 5.5 volt rail via R12. For the time being consider that the output of IC5 is low. When the voltage on C7 passes about half the rail voltage, the gate output goes low, turning off Q4. The collector of Q4 is the 'enable' line, which is used to activate other blocks. This line going high signals the arrival of the armed condition, which follows the exit delay.

If the ON line goes back to 0 V, as is the case when the ignition is restored, C7 discharges via D5 and R13. Q4 is immediately turned on and the enable line pulled low. If the low on the ON line is soon returned to a high, before C7 has half discharged via R13, rearming occurs at once.

In addition to the above mechanisms, if the output of IC5 goes high, corresponding to the alarm going off, C7 will be discharged, though the enable signal is not removed because it is discharged until both of the terminals are held at about 5.5 volts. However, when the output of IC5 goes low again, when the alarm ceases, the circuit goes through its normal arming procedure re-arming the unit to detect further interference.

The fourth gate in IC1, in conjunction with Q5 and surrounding components, forms the Lamp Driver. When disarmed, the $\overline{\text{ON}}$ line is high, and the gate holds Q5 off. R16 keeps a small current flowing through the lamp (about 30 mA) to keep the filament warm. This greatly prolongs the lamp's life. When the exit delay commences, the $\overline{\text{ON}}$ line goes low and Q5 is turned on by the gate. R15 limits the current into the globe. The value shown is suitable for a 6 V/100 mA globe, as is commonly fitted to the illuminated push buttons sold for the very purpose of car alarms in the suppliers around Sydney. Lamp life is also greatly enhanced by using a globe of lower voltage along with a series resistor, and this is what I elected to do. If you use a 12 V globe, you should substitute a 10 R, ½ W resistor for R15.

The Clock signal is provided by IC2, a 555 timer. When the enable line goes high the clock line is released from 0 V and oscillates between 0 and 5.5 volts at around 0.7 Hz. That gives one lamp flash or horn blast about every second and a half. This speed may be altered by varying C8.

The power supply for IC3, the Dash Panel Remoter, is derived from the ignition line by R21, zener ZD1 and C9. Thus, this subsection of the alarm is powered up only when the ignition line is on. When on, the supply is held near 10 V.

Initially, C11 will be discharged, holding the output to the warning driver low. Thirteen seconds or so are required for C11 to reach half the supply, freeing the circuit to respond to its inputs. This ensures that no indications are given during the initial starting period.

After a few moments, C11 will have charged up to 10 volts. C12 will be held near 10 volts also, and C10 will be still discharged. The output to the warning beeper will be low. If any of the connections to the diodes joining R22 and R23 go low or any connections to the diodes meeting R25 and R26 go high for sufficient time to charge their respective filter capacitors (about one second) the output is sent high and the warning beeper sounds. After another twelve seconds, C11 will discharge and again turn off the beeper, in order not to annoy if the indication is continuous.

After that interval the unit will have drawn the driver's attention to the problem anyway.

Clearly, the circuit need not be employed if not desired as it is not interlocked to the rest of the circuit. Conversely, it could be installed in a car without the rest of the alarm. (Apart, of course, from the addition of some beeping circuit.)

The microphone preamplifier consists of Q6 to Q8 and surrounding components. Q6 and Q7 form a high gain amplifier with voltage-sample, current-sum feedback. This arrangement provides a stable gain with no crosstalk between adjacent inputs. Q7 is acting as a current source load for Q6, which is a common emitter stage. Q8 is another common emitter stage with an emitter degeneration resistor to provide current sample voltage sum feedback.

These stages give gains of around 68 and 5, or a total gain of 340. The gain must be relatively stable and constant as the trip sensitivity of the alarm is dependant upon it.

The microphone amp output is applied to the trigger input of IC4, the Entry Delay monostable. When the voltage on pin 2 falls below one-third of the supply voltage, the monostable will trigger. The dc level on this pin is set by RV40 and accompanying resistors. C18 filters any spurious spikes while C17 couples the ac signal from the resonance microphones to the trigger input. Varying the dc level changes the mount of additional signal which must be supplied by the amplifier output to initiate the entry delay. This effectively sets the sensitivity of the alarm.

When the monostable triggers, pin 3 goes high. This applies a positive voltage to the base of Q9. Whenever the clock line is low Q9 saturates, turning on the beeper. Thus the beeper pulses during the entry period, warning the driver (or thief) that the system is active.

If the positive voltage is applied to the base of Q9 by the remoter, Q9 will turn on and emit a constant beep, as the clock line will be low (disabled or 'not enabled') whenever the ignition, and hence remoter, is on. R44 is provided in case you are using a beeper rated for less than 12 volts nominal (actually about 15 volts!), or in case you find the beeper is excessively loud. It may be shorted out if you have a normal 20 volt piezo type sounder.

When the ignition line is taken high, IC4 is reset, as well as IC5, cancelling all delays, etc. If, however, the monostable times out before this happens, as is hopefully the case if some naughty thief is tampering with your pride and joy, a negative going pulse is applied to the trigger pin of IC5, yet another 555 timer. The output of this circuit is fed to the Relay Driver and the Tell-tale Flip-Flop.

For the alarm period, the relay is pulsed by Q11 in a similar fashion to how the beeper is pulsed by Q9. At this time the effectiveness of the power supply is tested as there are typically very severe electromagnetic and voltage pulses emitted by the high power circuits.

If you are using a noisemaker which is self pulsing, or some sort of sonic defence system is connected, connecting the emitter of Q11 to ground will produce a constant output for the duration of the alarm period. Once the timer times out, the re-arming cycle initiates as outlined earlier. The duration of the alarm period is set by C28; the values specified give about one minute. This is less than is often the case, but the alarm will have done its work by then anyway. In fact, 40 seconds is probably plenty. (For this use 33μ or so.)

The alarm can be triggered also by a pulse from the perimeter loop control logic via C26. Two gates from IC6 comprise the loop sensor. The normally closed (NC) connection in series with R51 keeps C24 discharged. The nromally open (NO) link in series with R52 leaves C25 discharged. If the NC link opens or the NO link closes a positive voltage is applied to one input of the first gate and its output falls, triggering IC5 immediately. The second gate turns on Q10 if the fault condition occurs, even if the reset line is low and the Tell-tale Flip-Flop is not driving the LED. This indicates the condition where one of the loops has failed. The diodes D8 and D9 provide protection in addition to the internal protection diodes of the IC to ensure that even significant voltages applied to the loop connections cannot harm the IC. C24 and C25 provide filtering to prevent extraneous pulses from upsetting the sensor.

The second two gates of IC6 form a flip-flop to remember if the alarm has been tripped in the driver's absence. It is set by the output of the alarm monostable, and drives the LED D10. It is reset by the $\overline{\text{ON}}$ line, and hence the restoring of the ignition.

rower of the car he is effectively not given the option of inhibition! (Particularly useful if you are forced to leave your keys with an attendant in a car parking station.)

6). The power supply for the alarm circuitry is a particularly 'robust' design, in order to eliminate problems which can arise if the noisemaker draws large currents or develops strong interference signals. Hence the system can handle large and fast changes in supply without complaint. This allows the use of air horns and/or backup batteries should you wish. Performance is not compromised with a sick or flattish battery.

7). A dashboard failure warning indicator remoter is also incorporated. This is a circuit which emits a constant tone from the beeper if any crucial dash systems come on and remain on for more than 1.5 seconds. Hence, if an oil pressure warning light goes unnoticed, or the globe fails at a crucial point, a backup warning system is present.

If you ever have the fear that someone who has borrowed you car will not respond promptly to a glow in a warning panel, this is the system to relieve your nerves. Those who care to, can wire the 'low petrol' indicator to this, so that there is even more strong a warning just before you run out completely.

The remoter system waits about 20 seconds after the ignition is turned on and then starts to search the power supplies to the various connected dash indicators. If one goes active (either plus or ground as appropriate) and remains active for more than 1.5 seconds the beeper goes on for 15 seconds. Hence, in the case of the low petrol indicator, the sound only occurs when the lamp is pretty continuously on. If the alarm can protect the car when it is left alone, why shouldn't it do the same when it is being driven?

8). When installed as described, and with a main alarm noisemaker which is not accessible without violating the alarm (either a horn well concealed or a separate mechanism well away from prying hands) this alarm *meets all NRMA recommendations* for a vehicle alarm.

9). Finally, disarming occurs immediately when the ignition is applied, but immediate re-arming occurs if the ignition line does not remain on for at least three seconds. This means that a brief pulse may reset a trip but will leave the alarm armed. This can be handy in setting up, and makes it harder for inept fooling to bypass the system, or spurious glitches to cause disarming.

If the above points have not sold you on this project yet, you just don't love your car enough!

Construction

Before proceeding with details of the assembly and installation of this project let me say that a lot of care should be exercised here for three reasons: Firstly, the electronics will be stowed in some less accessible location in the vehicle making it tricky to access, even if you have the recommended connectors installed, and the sensors will be bonded solidly in various places around the body, so later corrections of errors will be painful. Secondly this is not a simple project, having two separate pc boards and a lot of interconnecting wiring in a small box, so mistakes are easier to make than normal. Lastly, sloppy or careless installation procedure can degrade the effectiveness of the whole project, possibly defeating its very purpose, so the moral is DON'T RUSH IT!

Two decisions are required before you leave the shop with the parts. The first is, namely, whether you intend to use the connectors in the cabling to permit quicker disconnection of the electronics from the fixed parts of the system. If you are dealing with a less accessible sort of car, or you cannot get a soldering iron to it easily, I *thoroughly recommend them.* Do not use the sort of connector that will work loose or corrode as these will surely cause more trouble than they save, but either go the 'whole hog', or wire directly. It will not affect operation — it is purely for your convenience. I will proceed assuming that you are going to use them, so just skip relevant parts if this is not the case.

Once you have have collected the electronic parts, unless you have bought a complete kit, you will have to go to a special supplier for the resonance microphones. The 'Microphone pickup' item on p.81 discusses places you are likely to be able to get these, though you may have to order them. They may cost from $5 to $15 each, or thereabouts, depending where you go to get them. If you have a small car, two microphones will most likely be enough. If you have a large vehicle or you wish to have 'hair trigger' sensitivity, four will be required. It is perhaps wise to get four if they are not too expensive to save another trip later, but it is also quite acceptable to get two or even only one and add more later.

Armed with all the parts, the next step is to retire to the workroom and assemble the control box. The first phase consists of preparing the box. Preferably using the blank pc boards as templates, position the two sets of mounting holes to hold the boards. I placed the smaller board against the lid and the other on the bottom of the box such that they swing apart when the lid is removed, almost using the flying leads as hinges. This makes for a neat and compact arrangement when assembled.

Only one further hole is required, being the access point for all the wires to the various parts of the car. This should be about 10mm in diameter, and preferably fitted with a grommet.

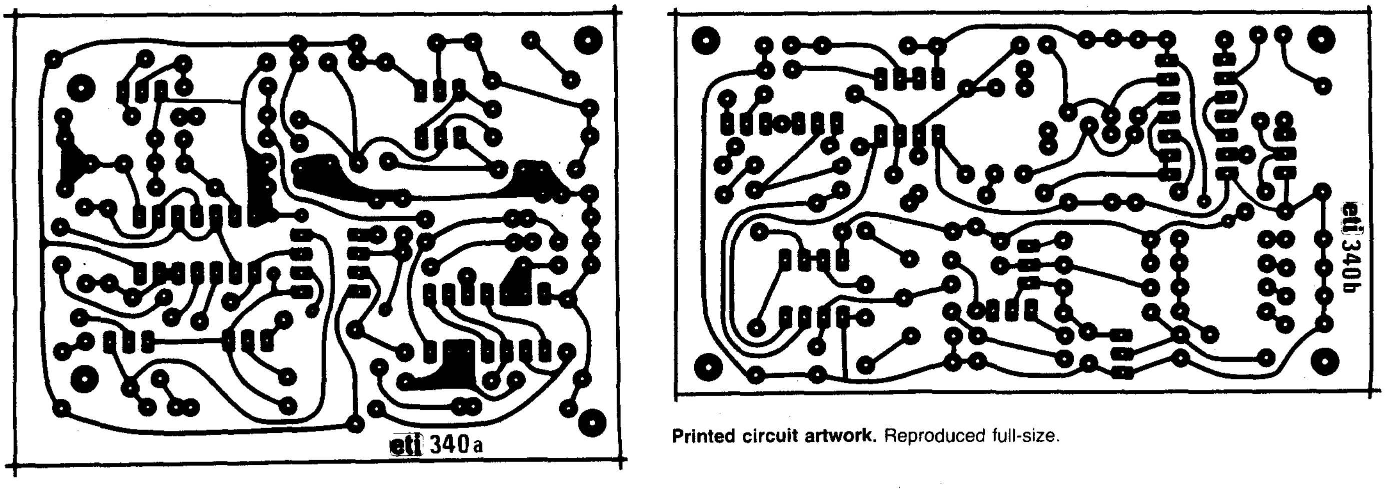
This done, assemble the boards according to the overlay diagrams. Remember, the resistors and some of the capacitors are the only parts which can be put in either way around — every other component will at least not function proplery and probably cause damage if inserted in any other way around than the correct way! It is best to insert and solder a few components at a time. Leave the ICs till last, but beyond this the order is irrelevant.

There are several links and flying leads involved, and it is perhaps best to do the links first, and flying leads last. You may like to insert each part in a logical sequence, following the circuit as you go to check the board. (The boards were fine when I last did it, but further checks cannot hurt!) Once soldered, trim the leads with side cutters, about 2 mm beyond the board surface.

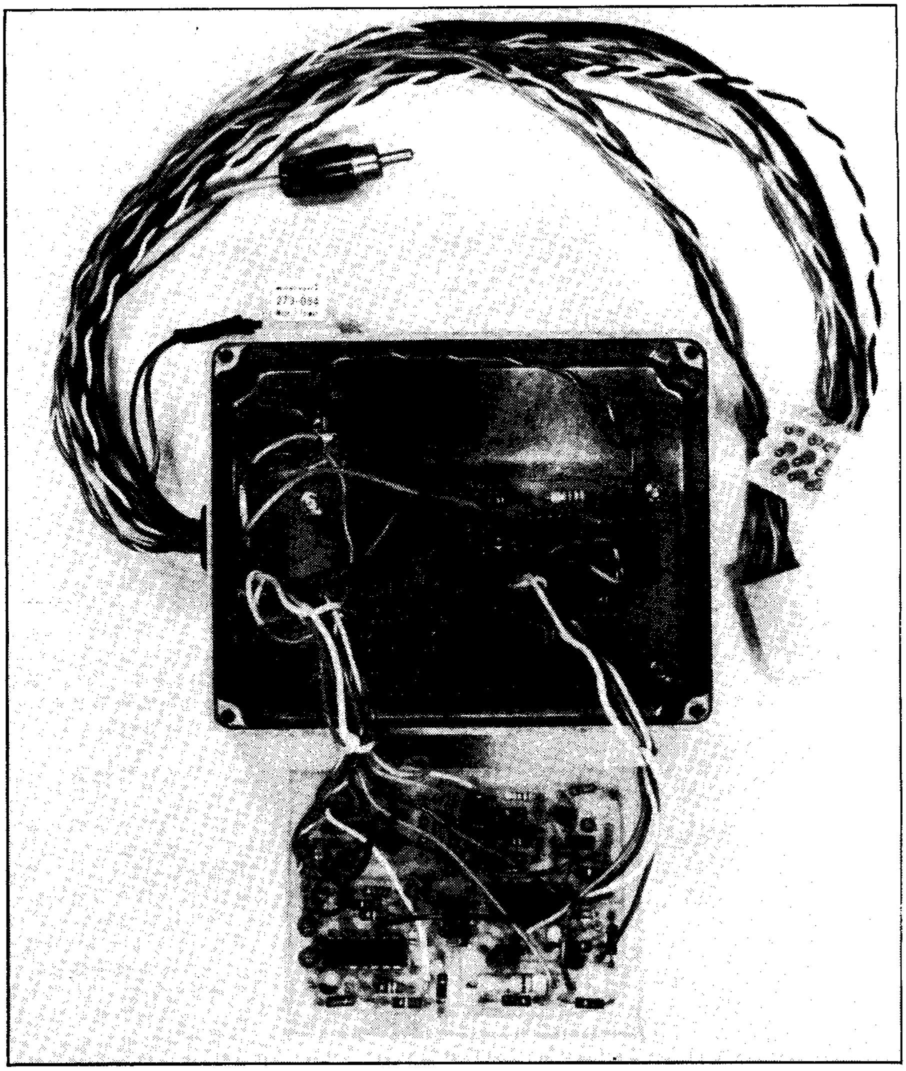
If you are using connectors as recommended, leave about 250 mm of wire attached to each connection which is going to the outside of the box. Otherwise you had better leap ahead and figure out how long the wire is going to have to be!

The relay is best attached to the inside of the box with double-sided adhesive tape, such as obtained from hardware shops. This method of mounting is remarkably vibration-proof, and overcomes the fact that relays do not often have mounting holes. Gluing it to the case with silastic is also effective.

The cables running from the relay to out-



Printed circuit artwork. Reproduced full-size.



side the box should be heavy duty ones (known as '24 x 0.2 mm'), preferably of the 'automotove' sort. This merely means that both the conductor and the insulation are rather thick. Do not forget that C23 must be soldered *directly* to the *relay terminals* along with D7. These components prevent the relay generating any interference.

If the box is to be mounted in the dashboard (see a little later) it is convenient to mount the noisemaker on the outside of the box, again with double-sided tape or with silastic (unless screw lugs are provided). If you are not sure, leave the mounting of this part until later. In any case, you will need to select the series resitor, R44, to match the noisemaker you have chosen. You will need to know how much current it draws if it is rated for operation below 12 volts maximum. I used a 5-9 volt type, and the resistor value marked on the circuit diagram was most satisfactory.

The value of the resistor is given by subtracting the working voltage from 13 volts and dividing the result by the current the thing draws at its working voltage $(R = (13 - Vw)/I)$.

Certain of the small noisemakers will act up if their supply impedance is not low. If you find it works on a supply of its working voltage but does little or erratic squarks when run with a resistor in series, place a 4-to-10 µF capacitor in parallel with it, at the noisemaker ends of the leads. This guarantees low supply impedance.

If it is not to be mounted in the dash, you will have to run the leads out, via a connector if it is to be installed permanently in the vehicle, or the leads must travel through a wall of the car.

INSTALLATION

With the basic electronic assembly finished, it is time to turn your attention to the vehicle. If you have a good service manual, the next step will be easy. It is necessary to determine certain connections within the vehicle's existent wiring.

The first line to identify is one which remains connected permanently to the vehicle's +12 V supply. If you cannot locate this in the paperwork which goes with the car you will have to do a lot of trial and error poking. If there is a dash clock it is likely that it will have an earth and +12 V continuous connection, as well as a line to light a globe when the car lights are on. This may narrow the field a bit, as will any appliance which remains operational when the ignition key is removed. The second line required is the ignition. This may be found near the key switch if accessible, or near an appliance which goes off with the ignition.

Horn connections

Next, the horn connections must be found. Some cars have a pair of wires leading to the horn switch, while others have only one, which is grounded when the horn is to be turned on. It does not matter whether you get into the circuit before or after the relay, if there is one, though before is clearly the desirable option. Some cars (e.g: VW) turn the horn off with the ignition. In these cars you must connect after the relay or directly to the horn. (More will be said later.)

Indicators

The above are the only necessary connections for the alarm part to be able to work by itself, but the remoter circuit will require one connection for each indicator to be monitored. I recommend that the 'charge' and 'oil pressure' lamps at least be remoted. You may wish to include 'temperature' if this is a lamp, not a gauge, or 'low petrol' or 'low oil' or 'low windscreen washer water' if you really want to cover every possibility. I think that such paranoia is unnecessary if you are not forced to let your pet out alone with other people on a regular basis. (I connected the 'low petrol' warning to annoy a lady friend sufficiently to prevent the car being returned near empty. Such measures are strong, but *eminently effective!*).

Anyway, back to the task at hand. A wire must be located (for each lamp to be remoted) which swings to rail or ground when the warning lamp illuminates. This is not hard, especially if you have the ETI-325 Auto Probe. It is best to write down each of the connections you determine. If you have a manual, write this information there, as it will be where you first look next time.

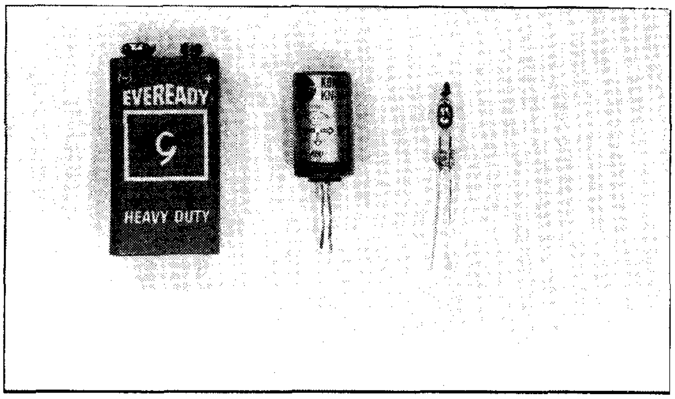
If you are in the habit of placing a circuit diagram of a project in the box along with the boards, this is also not a bad place to scribble the notes.

It may come to pass that all the lines you need to monitor with the remoter go either to ground or rail. That is, they all go to only one; in this case the part of the circuit which monitors the other option can be ignored, reducing the count of wires leaving the box by one. This will be mentioned when it comes to the wiring up.

Control box

Having located all these connections, the location of the control box can be sensibly decided. In most cases it will be more convenient for it to be located in the dashboard, but it can be in the boot or the engine bay for that matter, if it is convenient. It should be out of easy sight and away from where it might be interfered with quickly. A spot near access to the wiring harness is good, as cables will lead to various other parts of the car including the battery storage compartment, etc, and these can follow the wiring harness through the holes in the panels. Do not attach the box yet; merely sort out the location.

Given the location of the box, decide how long the wires between the box and the connectors need be. *In case of failure, or the* need to check wire continuity, etc, the con- ▶



Take care. There are mercury switches and mercury switches. The two common types are shown here, compared to a 9 V battery. The glass type on the right is theone to get, the type in the middle of the picture proved unreliable.

nector should be a little easier to get at than the box. If the box is to be in a location not accessible without tools, it is a good idea to place the connectors where they are easily reached (once you know where to look). Fit the connectors now.

Next, run cables from the car side of the connectors to the +12 volt line, the ignition line and the chassis (ground). Run a pair of wires from the connector to the nearest hinge of the compartment where the battery is mounted, leaving about 400 mm extra cable free, for the time being.

Battery protection

Clearly, if you have a car such as a Skoda or Mini, where the battery is stowed under a seat in the passenger compartment, it may not be necessary to put special protection on this bay, but in general it is necessary to connect a switch to the compartment cover to trip the alarm immediately if the bay is opened.

If you do not do this, it is possible to simply defeat the alarm by entering the car normally, opening the bonnet, say, and cutting the battery connection before the entry delay is over.

Such protection is most easily and reliably provided with a mercury switch. I recommend the kind of mercury switch which is glass encapsulated. These will most likely cost from $1 to $2, or so. The plastic-cased ones tend to be unreliable in the long run, so I recommend avoiding these if at all possible.

Run the cable to the hinge in such a fashion that you will be able to leave a loop free, so as not to unduly tension or twist the cable each time the hood is opened or closed. Locate a suitable position where the switch can be attached and where it will be tilted off when the compartment is closed and on when it is opened. Do not forget to leave a safety margin in case the car is parked on an incline! If this were to happen, the rest of the alarm would still work perfectly, but the loop failure warning would be given and the loop protection circuits would be disarmed.

Cut the wire to the correct length, and carefully solder on the mercury switch. Insulate the connections with small lengths of spaghetti heatshrink tubing, or insulating tape. Next attach the switch. This is best done either using tape to bind the switch to the end of the hinge bracket or perhaps using the very strong double-sided adhesive tape to stick it to the flat surface of the cover.

Another method involves connecting the switch to a small aluminium bracket by means of binding tape or heatshrink tubing, then screwing the bracket on with a small self tapping screw. This can be tapped into one of the structural ribs of the metalwork of the cover panel. Check that it goes open when the cover is closed, and closed when it is opened. Connect the second wire of the pair to the +12 V rail at the connector.

Accessories

Next, if you intend to protect driving lights, or some other electrical appliance using the normally grounded connection to the alarm, run a cable from the connector to the appliance. The cable can be connected immediately to the chassis at the connector if you do not need this option. At the light or whatever, connect the wire to a normally grounded point.

On a radio or similar, this is the case of the unit; on a lamp, connect to the centre (active) conductor.

When off, this cable is at earth potential, by virtue of the low cold resistance of the lamp filament. If you use the above technique to protect a lamp, you will avoid the necessity to make a separate connection to the metallic body of the lamp housing, which can be quite tricky. the only thing to note is that the loop failure indication will be given whenever the lamp is on, because the active connection will not be at ground potential.

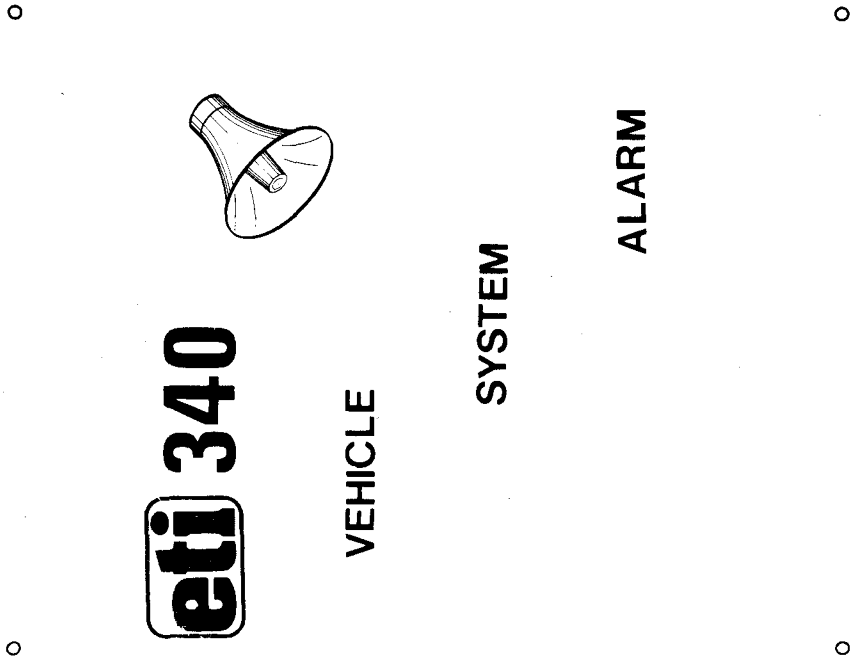
Run the wires from the connector to the point where you intend to tap into the horn circuit, if you are using the horn. If the horn in the car is accessible from outside, or without opening the compartment previously protected on account of the battery, you may choose to use a separate noisemaker, such as a siren, rather than the car horn.

Presumably for reasons of potential tampering, the NRMA recommends that a separate siren always be employed. This is sensible, but unnecessary if you have effectively rendered the car horn tamperproof by the above measures for protecting the battery compartment. At any rate, do not actually connect the noisemaker at this stage, as there is a lot of testing to be done later, and there is no sense in crying wolf or giving yourself an earache unnecessarily.

Microphones

Now the microphones must be fitted. Each one must be glued carefully in place after the surface has been carefully prepared. The selection of the locations requires some careful consideration, and the gluing some time, so leave yourself with plenty of time for the chore.

The locations you choose should have



Front panel artwork. Full-size reproduction — covers the box used.

two properties; between them you should achieve good coverage — that is, there should be an even distribution of them all over the body. Secondly, each microphone should be secured to a fairly large piece of the body or chassis in order to get good solid sound connection to the nearby body panels. Remember that sound travels much better in solids than it does in air, and much better in rigid and hard solids than it does in soft ones. Hence, it is good to place a microphone on to a solid piece of the body framework, such as the part where the door hinges are attached, or the front wing panels just in front of the door hinges. It is unwise to secure a microphone to plastic or flimsy plates of thin metal.

While glass would otherwise be a very good choice, it is also not wise to attach to windows, because the rubber mounts which hold the glass tend to insulate the glass from vibration, and hence sound.

If you have a small car, two microphones will probably be sufficient. They may be best deployed one on either side, or perhaps one front right and one left rear will be best. It is dependent upon how the car is constructed and where solid panels are accessible.

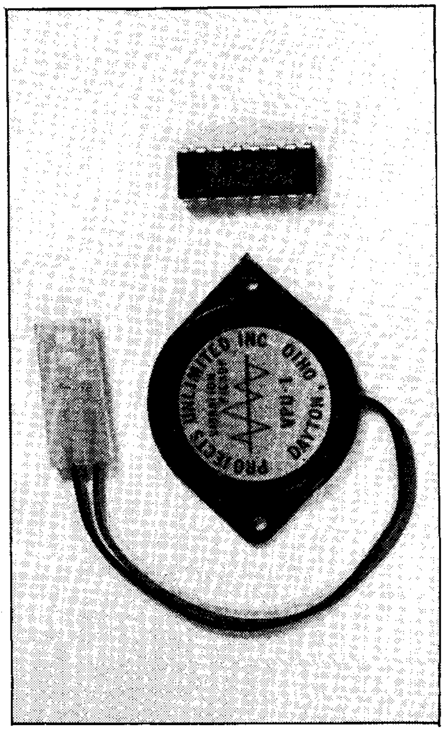
A larger car might be dealt with by having one microphone in front of each front door, and one at the rear where the bumper bars are attached. A very large or long car might have four, one near each corner panel. A utility will need four, two near the cabin, and two at the end of the load area.

It is a wise idea to cover the driver's door more carefully as the sound of the latch being opened is less than the sound of someone scraping the front paintwork. Thus, you need to be closer to the latch than you do to the front extremity. Though it is unlikely that a thief will take time to try and unlatch the door very quietly, this also suggests the need to have microphones near the doors.

If you have access to an oscilloscope, you can employ one microphone, before attaching it permanently, as a stethoscope. Connect the microphone to the CRO and set the screen up where you can observe it while walking around the car. Get an assistant to hold the microphone against small flat sections of the body at various potentially permanent locations. Tap the car at various locations with a coin, say. (Don't scratch it!). You will observe ringing waveforms at around one kilohertz. The location which gives the biggest waveforms when the car is tapped in the area you want to protect is the best one to choose.

Having settled on the locations, clean each one carefully. Acryllic thinners proved the best solvent, but Prepsol or even methylated spirits will do at a pinch. If the area is covered with a thick antirust covering, this should be scraped back in the immediate vicinity. If the paint is gloss, not matt, this should be rubbed rough with a small piece of emery paper of 400 grade or so, in order that the glue will adhere.

For the gluing, use only an epoxy adhesive. Do not use a contact adhesive, a cyanoacrylate glue (such as 'Superglue') or any silicon rubber glues. I strongly recommend Araldite, but any epoxy type glue that sets rigid should do.



Microphone pickup. This shows a ceramic 'vibration microphone' that may be used with this alarm, compared to an IC for size. This model is available from Creative Electronics, PO Box 240, Matraville, NSW 2036. (02) 666-4000. If you use this type, reduce C13 to 100n (tant) and increase R27-30 to 47k (this may need adjusting to set correct sensitivity).

Other types of pickup, the 'resonance microphone' type, are available from Tandy Electronics as accessories for their 49-762 alarm. ▷

Coat the surface to be used with the glue, and press the microphone, flat face down, against the glue patch. Squeeze out any bubbles. Wedge the microphone in place and allow it to dry completely. If you move the body of the sensor just before setting, you may destroy the close mating of the microphone to the panel, reducing the effectiveness of the job quite considerably, so be sure to allow plenty of setting time. This will be longer than advertised on the packet if the weather is cold, so leave a safety margin.

When the glue is set, run the cable back to the control box and then attach the plug to the cable, if you are using it. The connection is made now rather than right at the start, because the connector would make the job of running the cable through any small openings much more difficult.

Lamps

Next, the connections to the lamps to be remoted must be made. You will require one diode, a 1N914 or EM401 or similar, for each lamp. If the active line of a lamp goes to ground when it is illuminated, it should be connected to the cathode of the diode, and vice versa. Then all the anodes of diodes to lamps which swing their lines to ground should be joined, and this common line run to the appropriate pin on the connector to the control box.

Similarly, all cathodes of diodes to lamps which are wired the other way should be joined, and the common connection run to the other remoter input, which should be labelled 'normally low' or 'high to alarm', or similar. If all lamps go one way, as is often the case, the other input may be ignored.

Button and tell-tale

Finally, the illuminated pushbutton and the Tell-tale LED should be installed. The location of these is up to you of course, but it is recommended that the lamp be prominent, as the flashing light does more than half of the protection involved with a car alarm. The LED should be either close to the lamp for convenience, or in some less significant location so as not to be intrusive.

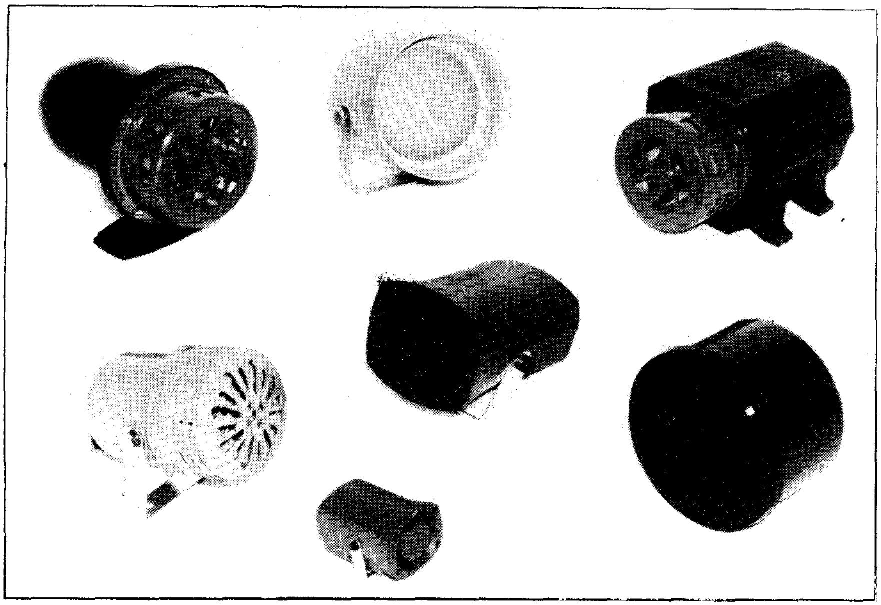
Where fitted to a motor bike, the considerably smaller battery may present problems. In this case, where the bright lamp is less of a vital concern, because it will be easier to see, certain power reduction measures can be taken. The lamp may be replaced by an LED. In this case the 390R resistor (R16) should be placed in series with the LED, rather than in parallel with the lamp it replaces. Current drain is then reduced to approximately 30 mA, or 40 mA (armed) at most. On the other hand, motor bikes can usually be kick-started, circumventing flat battery problems, whereas a car is typically not provided with a crank, as all once were!

An interesting side effect here is that the usage which the alarm makes on the battery can prolong its life. Batteries like to be used. If your car is one that regularly starts on the first turn, the battery is getting almost no use at all.

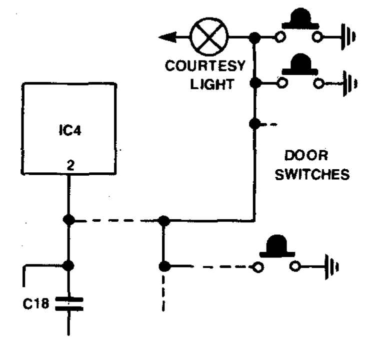
A previous ETI project — the Expanded Scale Ammeter (ETI-329) — clearly evidences the fact that the car's alternator can replenish the energy used to start the engine in 15 to 30 seconds. In fact, the more sophisticated car electrical systems coming out of Europe these days are actually organised to use the battery, permitting its partial discharge under some circumstances, such as night driving. This deliberate forcing of the battery to deliver power over a period of time improves its chances of being able to do it when needed at short notice, or so the theory goes.

Special protection techniques

The main complaint levelled at car burglar alarms is that they merely make a little noise, of which no-one takes any notice. This is generally not the case, as people love to see whose alarm has gone off, although they have little intention of acting on the information. In itself, this is good protection because thieves rely upon being inconspicuous. In addition, many people are rarely out of earshot of their own cars, and ▶



Noisemakers. This picture shows the variety of noise makers you can use if you decide not to use the vehicle's own horn. And all of these are available from one firm! This range (30-XXXX series) is distributed by Benelec, PO Box 21, Bondi Beach, NSW 2026. (02) 665-8211.



'SWITCH CLOSURE' ENTRY DELAY

In some instances or situations you may

you quickly learn to respond to the horn you know to be yours! However, it is true that the alarm does not render the car unstealable.

Several tacks can be taken to enhance effectiveness, even strictly within the law. The first consists of installing a latching relay which isolates the ignition or starter relay supplies.

In some cars it is easier to hotwire the ignition by placing a patchcord directly from the battery to the coil. In this case interrupting the ignition wires is *hopeless,* as they are all bypassed immediately anyway. Where the battery is in the engine compartment this technique is so easy as to make the effort wasted, if another jump is tried, so turn your attention from the ignition to the starter system.

The wire running to the starter solenoid is the best to interrupt, as few thieves bother push-starting. The circuit modifications required to implement such a system are shown in the adjacent circuit diagram. It is necessary either to remove and replace the battery connection with the ignition on, or to have a concealed reset switch, in order to reset the interlock, but then that is not a large price to pay and is unlikely to be tried by a thief endeavouring to quickly and quietly slip away with the car.

It is necessary to have a relay with two contact pairs in the alarm itself if you are using this circuit, as well as the additional relay.

Mount the isolator relay in a concealed area, so as not to make its presence too obvious. Try to cut the appopriate wire where it is not plainly visible, in case the thief notices this and bypasses it at once. The relay you use need not be rated to switch more than two amps or so, even if the solenoid is rated much higher, as the relay will probably never actually interrupt the supply while it is on.

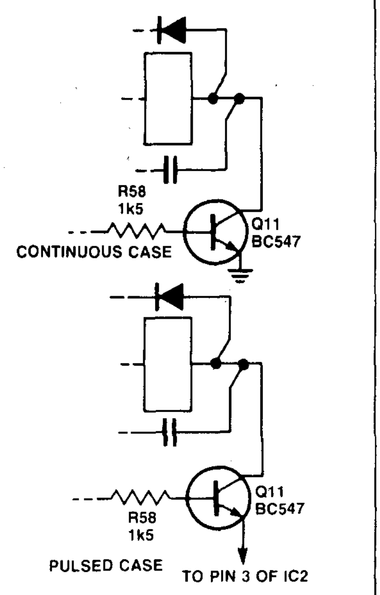
These methods are, however, a bit messy, and do not stop the thief pinching things from the cabin. They are merely a hindrance to taking the whole car, and also represent a lot of fiddling with the car's electrics, with possible reliability problems. A favoured idea in certain foreign climes consists of putting a *very loud* noisemaker actually inside the cabin. The idea behind this is simply to drive the thief out by sheer sonic power.

Air-type sirens can be purchased which deliver sound levels of 120 dB at one metre. These are ideal for the job. The rear parcel shelf of a sedan is a suitable place to mount such a mechanism. It can be connected in place of the horn as the central sound generator, because sufficient noise leaks out of the cabin to attract attention, even with closed windows and doors.

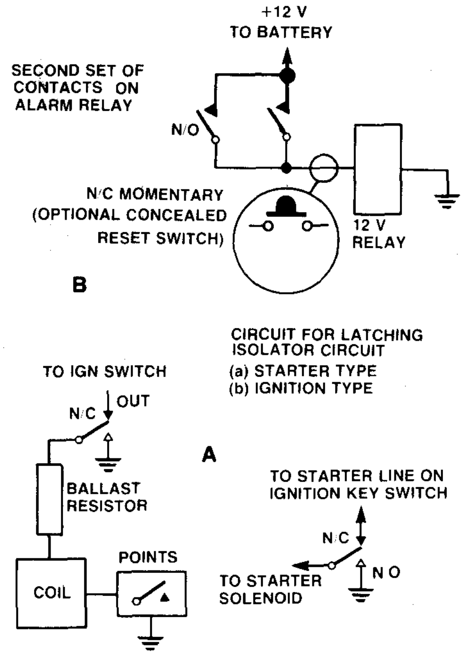
If you need it to run continuously, rather than in a pulsed fashion, a small modification is needed to the alarm circuitry. Return the emitter of Q11 to the 0 V line, rather than the clock line. This will cause the alarm relay to remain latched rather than pulse for the alarm duration. This modification is details in the accompanying circuit.

If you do not mind the warning buzzer set for continuous rather than pulsed operation as well, the modification is quickly implemented by changing the flying lead from the emitters of Q9 and Q11 from the other pc board to the 0 V line (ground).

If thieves get away with your car after all this — wish them good luck and go see your insurance firm! ●



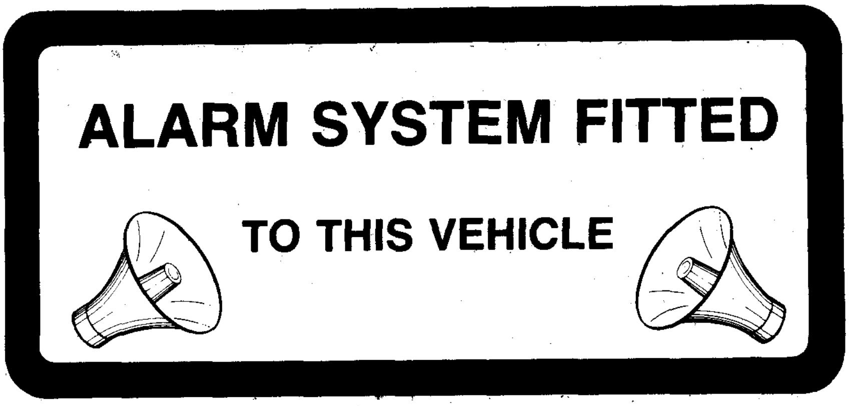
MODIFICATION REQUIRED FOR CONSTANT ALARM (INSTEAD OF PULSED)


+12 V
TO BATTERY
SECOND SET OF CONTACTS ON ALARM RELAY
N/O
N/C MOMENTARY (OPTIONAL CONCEALED RESET SWITCH)
12 V RELAY
B
TO IGN SWITCH
N/C
OUT
BALLAST RESISTOR
COIL
POINTS
A
TO STARTER LINE ON IGNITION KEY SWITCH
N/C
N/O
TO STARTER SOLENOID

CIRCUIT FOR LATCHING ISOLATOR CIRCUIT
(a) STARTER TYPE
(b) IGNITION TYPE

consider it desirable to have a switch closure activate the entry delay, rather than trip the alarm immediately. An example would be using the 'courtesy' light switch in a door. Some cars have door catches which don't make much noise (a noisy catch tripping the alarm) or have doors which are heavily sound-damped, such as is the case with Rovers, Mercedes', Rolls Royces (. . . we like to cover *all* our readers!) and some Peugots, etc.

Using the courtesy light switch to set off the normal entry delay is illustrated in the circuit here. All you need to do is link pin 2 of the 555 entry delay timer (IC4) to the 'lamp' side of the door switches via a diode.



Project 1516

The 'sure start' model engine ignition system

No more flick-flick-sputter, flick-flick-sputter. This 'glow plug regulator' ensures a lively start for that model petrol engine in your favourite model aeroplane, boat or whatever.

Jonathan Scott

HOW MANY OF YOU have one of those infernal model petrol engines lying around the garage or store room somewhere? And why exactly are these things so often left unapproached and undisturbed in these dark crannies — because they are noisy? No. It is usually because they are *so difficult to start* that you have decided that they are not worth the trouble or the cost.

I recall spending ages as a kid with model aeroplanes trying in vain to get them going, wearing my fingers to the bone — flick, flick, flick . . . and no start. Often they would appear to kick over, encouraging the soul, only to remain in that half-starting phase turn after turn.

I gave up then — anyone with any sense and/or no money does. Yet, with the development of the 'magical' ETI-1516, friends and relatives have been volunteering their discarded models for testing, encouraged by the effortless instant starts which can be produced on demand. (The author had already bought several engines and wasn't interested in any more, thank you.)

So this project should provide the incentive to resurrect that long-stored model with the promise of quick ignition which, we hope, will encourage you to give it another go. After all, for under $40 plus fuel you can buy a complete aeroplane kit including the engine and all the accessories to have the thing flying on a control line almost instantly.

Ah, but the experts (read fanatics if you like) seem to be able to get their models to go promptly, so you might think that the complexity of the ETI-1516 is rather unnecessary. What do the regular modellers use to get the same end?

Firstly there is experience. They have probably been just where we have but they didn't give up, the blockheads. However, the endless tinkering and fiddling has payed off; they have tried all the possibilities and learnt to tell quickly what is the problem. Too much fuel or a flat-ish battery are dead giveaways when you have been at it for life. Misadjusted mixture takes thirty seconds to spot with enough experience, while a major failure may be the only problem not eliminated after two minutes.

All this is fine, but useless if you don't have a pet modeller on hand. Next, there are the current commercial inroads made by electronics which are available at the model shops. For around $30 you can buy what is termed a 'power board'.

This thing connects to a car battery and allows you to deliver 0 to 5 A to the plug while giving a rough indication of current by means of a meter. It is basically a single transistor or Darlington and a few resistors, and not surprisingly delivers a lot of heat to the atmosphere and the unwary modeller's fingers! Also, of course, it takes the same current from the main 12 V battery as it delivers to the plug, necessitating the use of a car-sized battery rather than a small set of sealed cells.

Again, with experience, but less this time, you can adjust it neatly so as to allow starting without regular incineration of the glow plug.

But for a similar outlay, our new unit is significantly superior in its operation. Firstly, it regulates not the current (bad) or ▶

the voltage (better) but the actual resistance of the glow coil, and hence the temperature of the plug (best).

Secondly, it employs a switchmode supply, which means that it dissipates only a modicum of power, typically five watts, rather than something over 50 watts.

What is more, it draws only a small fraction of the current that it delivers to the load, typically 20 to 25%! Result: less of a heat problem and smaller batteries for the same performance (penlite NiCads are fine) or even longer, lighter wires, running to your car cigarette lighter or whatever.

In addition to these features, it has a few more. It is cleanly and sharply current limited, which makes it infinitely harder to ruin a glow plug. We have equipped it with a button to allow the current meter to act as a battery check meter.

It has two potentiometers which are alternately selected by another switch: these can be preset to provide the correct starting temperature for two different engines or two different grades of glow plug for the one competition engine.

In case you thought that 'glow plugs was glow plugs' then it is about time that you took another wander through a model and hobby shop and saw the range of glow plugs which are available for tuning your engine. There are even several devious speciality twists you can get for improving some aspect of the running performance.

These features put the ETI-1516 ahead of anything commercially available, and coupled with its relatively simple construction and lack of critical or rare components, we feel it is the best option both for those not heavily involved in modelling and as a replacement piece of equipment for the serious model enthusiast.

Construction

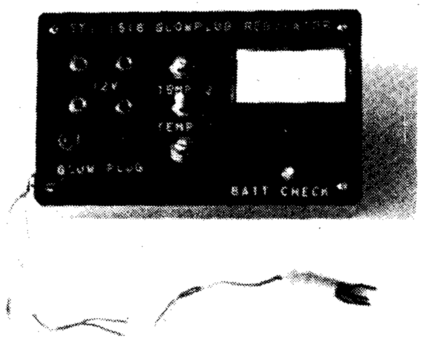
The commercial power boards I saw sold at hobby shops are constructed on a small flat plate of aluminium with the components mounted by bolts or silicone glue, to the back of the plate. The user is presumably free to mount this plate in a box or use it as is.

Out of a desire to conform to the expected structural format, I built one prototype on such a small plate, but it is the front panel of a jiffy box, so that you have a ready-made enclosure if you want.

If you are not concerned with the compactness or the appearance but rather the robustness, I recommend using a tent-shaped panel quickly bent up from 14 or 16 gauge aluminium sheet or similar.

This structure provides its own heatsink/mount for the power transistor (Q7), as well as allowing access to the innards at short notice (very handy with the situations you find cropping up on the runway when you're miles from home). I built another unit like this. If your metalworking facilities do not stretch to this, the jiffy box is easier to prepare.

Also provided as a convenience, because commercial units often have it, is a second pair of banana sockets for the 12 volt supply so that more than one device running on the same source can be accommodated simultaneously without piggyback plugs. This can be deleted if you prefer.



Jiffy box model. This one I constructed on the metal lid of a suitably-sized jiffy box.

Perhaps the first stage to construction is the winding of the coil, L1. I wound about 50 turns of 1.45 mm (15 B&S) enamelled copper wire on the former of an FX2243 45 mm diameter potcore assembly. This produces 20 mH inductance and is easy to buy and wind. In fact, any value of inductance from a minimum of about 5 mH up to 50 mH will do, but remember that it must be wound of wire sufficient to handle five amps. I suggest that you use 1.45 mm diameter wire, but at the very least 1 mm wire might do as the unit will not be used continuously. This inductor is the bulkiest component, so choose the box you wish to use with an eye to the size of this as well as the meter, M1. The next stage is to drill and prepare the front panel. My advice here is not to go overboard on the cosmetic side as the working environment and chemicals will make a mockery of any efforts at glamorous packaging.

While indelible pen is probably the most cost effective method of marking the front panel, I sprayed it with aerosal paint and marked the controls with labels on one prototype which were later covered with some clear lacquer. The result is clear and durable.

If you have the panel area, the pc board can be mounted on it. I have made provision for mounting holes on the board.

Next mount all the panel components. I used pots with the short ribbed spindles and screwdriver slots, intended as 'chassis presets'. I recommended them as you do not want to alter the settings often and knobs make it likely that there will be some potentially hazardous (to the glow plug) twiddling by well-meaning or curious persons.

For the pushbutton, SW2, I used one of the small positive action momentary switches which cost a little more but are crisp in their action and fairly robust.

Now comes the assembly of the pc board. Two factors are worth noting. Firstly, if there is no chance of the incoming polarity being reversed, forget D3, the supply protection diode. Otherwise fit it either as I did, between the pc board V+ connection and the lead going to the terminal, or at the incoming terminal junction.

You could even fit it in such a fashion as to protect components further down the chain by placing it between the first and second positive input banana sockets.

I used the banana sockets as these are what the commercial units are normally equipped with, but a polarised-type plug would be preferable as D2 can be dropped and then you can run to a lower input voltage before the electronics gives up.

As the voltage coming in to the box must run the op-amp, it is desirable to keep the input as high as possible. My prototype ran down to 9 V (after D2) comfortably.

Warning: polarity reversal will be quite lethal, so use D2 if you are not otherwise guarded.

The second factor concerns the heatsink on Q1. If you will not be running the unit for more than one or two minutes at most (the usual case), about 3 cm x 3 cm of heatsink is quite adequate, but a 6 cm x 4 cm heatsink at least must be used if you wish complete protection from burnout in continuous operation.

The consideration of operation duration also effects the choice of D1, the freewheel diode. It should actually be rated for about four amps continuous forward current but a three amp diode will be quite safe if you are only running it for a minute or two at a spell. Five amp diodes are more costly and harder to get, and our unit ran quite well using a three amp type. Higher current diodes tend not to be pigtail types too, which complicates mounting.

HOW IT WORKS — ETI-1516

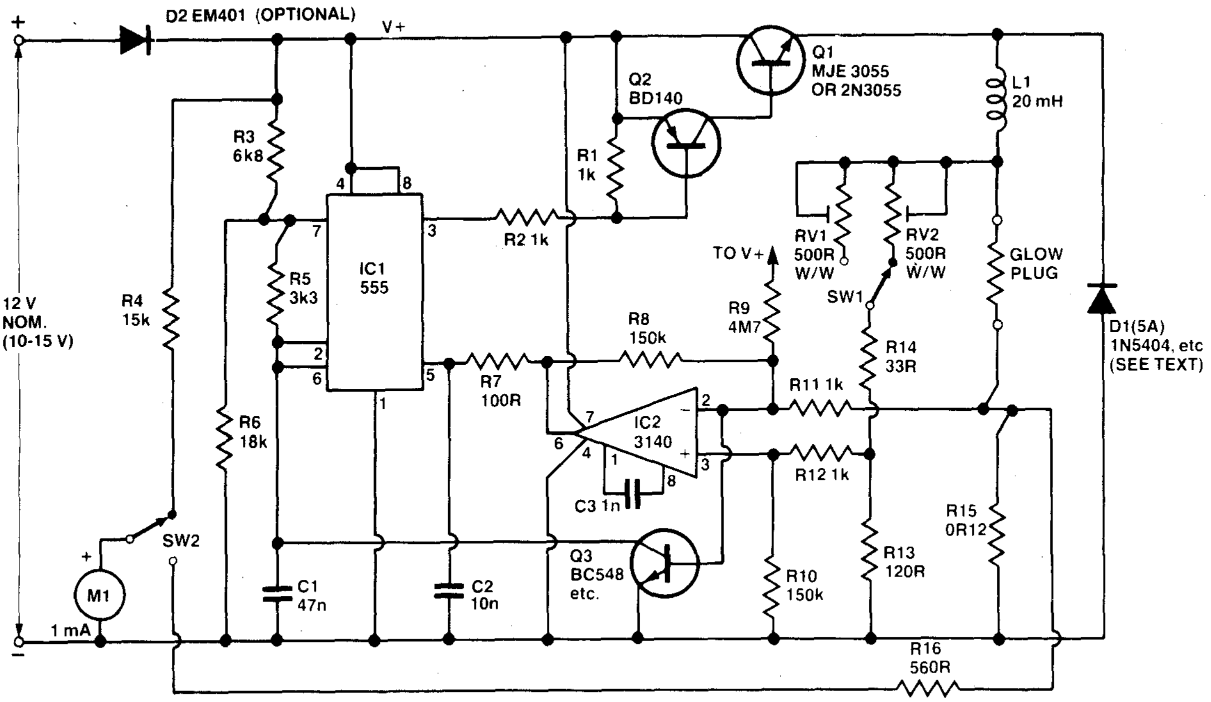
The block diagram of this unit is shown in Figure 1. There are three main parts to it: the resistance 'bridge' and the bridge amplifier, the pulse generator and the switching regulator.

The pulse generator provides constant-width pulses at regular intervals to the switching regulator. This provides current to the bridge, most of which (I_L) flows down through the glow plug (R_L) and a low value resistor (R_S). The ratio of R_A:R_B is compared to R_L:R_S by the bridge amp. If the ratios are different, then a voltage will appear across the op-amp inputs. If the glow plug (R_L) is cold, its resistance will be low. The ratio of R_A:R_B is set such that, when the glow plug is cold, R_A:R_B is greater than R_L:R_S.

Under these circumstances, the output of the bridge amp will cause the pulse generator to speed up, increasing the output of the switching regulator which then drives more current through the glow plug. The glow plug's resistance then increases and the ratio of R_L:R_S decreases. This causes the bridge amp to slow up the pulse generator until R_L:R_S equals R_A:R_B. i.e: the bridge is 'balanced'. The pulse generator then provides pulses at such a rate to the switching regulator so as to maintain the resistance, and thus the temperature, of the glow plug as desired. Varying the value of R_A thus sets the temperature of the glow plug.

Note that the majority of current supplied by the switching regulator passes down the R_L-R_S 'leg' of the bridge, only a small amount passing down the R_A-R_B side. The load current (I_L) thus flows through R_S and the voltage across R_S is used to drive the current-limit circuitry.

Looking at the circuit, the bridge consists of RV1/RV2-R14 (R_A), R13 (R_B), R15 (R_S) and the glow plug (R_L). The bridge amplifier comprises IC2 and associated components. The pulse generator is provided by IC1 and associated components while the switching regulator comprises Q1, Q2, L1 and D1. The voltage drop across R15, through which the glow plug current



(I_L) flows, is sensed by Q3 which provides current-limiting.

Initially, C1 will be discharged and the output of IC1 will be high (i.e: at +12 V). Thus Q2, and therefore Q1, will be biased off. C1 will begin to charge via R3 and R5. Now, the inverting input of IC2 has a small positive bias applied to it via R9 and thus IC2's output is low (0 V), pulling pin 5 of IC1 (the control pin) low. This allows the 555 to trigger its output to the low state after C1 has charged only a little way.

When pin 3 (the output) of IC1 goes low, Q2 will be biased on, turning Q1 on. This applies 12 V to L1 and current will commence to flow through L1, the glow plug and R15 (also a little through RV1/RV2-R14 and R13). Because of the inductance of L1, the load current (via the glow plug, etc) will rise slowly. As the glow plug is cold to start with, the ratio of the glow plug resistance to R15 will be much less than the ratio of RV1/RV2+R14 to R13. Thus, the voltage at the inverting input of IC2 will be greater than that at the non-inverting input and the output of IC2 will continue to hold pin 5 of IC1 low. Thus, Q2 and Q1 will remain on, allowing the current through L1 and the glow plug to continue building up.

When IC1 first triggers, pin 7 goes low and C1 will begin to discharge via R5. The output of IC1 will remain low for as long as it takes C1 to discharge to half the level it was previously charged to, at which point pin 3 of IC1 goes high again and Q2-Q1 turn off.

The magnetic field built up in L1, having nothing to sustain it now, will begin to collapse, the voltage across L1 will reverse and forward bias D1. Thus, the current generated by the collapsing magnetic field in L1 will continue to flow through the glow plug and R15, but now via D1.

The current now supplied by L1 will fall as the coil's energy is dissipated by the glow plug and R15. As the glow plug is still relatively cold, the inverting input of IC2 will be higher than the non-inverting input as the voltage drop across the glow plug will be less than the voltage drop across RV1/RV2+R14. Thus, IC2's output will hold pin 5 of IC1 low, allowing C1 to charge again.

When pin 3 of IC1 went high, pin 7 also went high, thus allowing C1 to charge again. When the voltage across C1 reaches the trigger point of IC1, pin 3 again goes low, turning Q2-Q1 on again.

Once again, current is applied to the glow plug, which continues to heat up. As the glow plug heats up, the voltage on the inverting input of IC2 will eventually reach that on the non-inverting input and the output of IC2 will then switch to the high state. This drives pin 5 of IC1 high and pin 3 low once C1 has completed its current discharge cycle.

The time taken for C1 to discharge will remain constant irrespective of the level on pin 5 of IC1. Thus, the pulses produced by IC1 will be of constant length, but the level on pin 5 will affect the pulse rate. If the glow plug is cool, the pulse rate will be high. As the glow plug heats up and its resistance increases, the pulse rate will decrease.

With IC1 operating at a high pulse rate, Q2-Q1 turn on more frequently, delivering a lot of power to the glow plug. When IC1 operates at a slow pulse rate, less power is delivered to the glow plug.

Switch SW1 selects either of the two preset pots, RV1 or RV2. As the setting of these determines the ratio of R_A to R_B, they will determine the ultimate temperature of the glow plug.

If the current through the glow plug exceeds that necessary to develop a voltage drop across R15 of about 0.6 V (about 5 A), then Q3 will be biased into conduction. The collector-emitter junction of Q3 then shorts C1, preventing IC1 from firing, turning Q2-Q1 off until the current through R15 drops below the limit. Thus, the current through the glow plug is limited to a safe value, preventing burnouts.

A 1 mA meter is used to monitor the supply voltage and the glow plug current. Resistor R4 provides the meter with 1 mA of current at a supply of 15 V. Resistor R16 provides 1 mA of current through the meter when 5 A flows through R15. Switch SW2 allows switching the meter so that it reads supply voltage and glow plug current as you wish.

Capacitor C2 protects IC1 against 'spikes' present on pin 5 of IC1. Capacitor C3 compensates IC2.

A diode, D2, may be added to prevent damage to the unit should the supply be connected in reverse polarity.

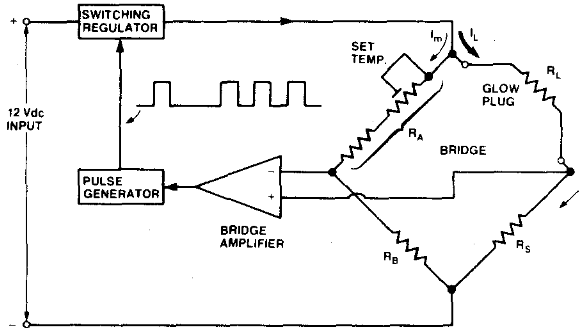
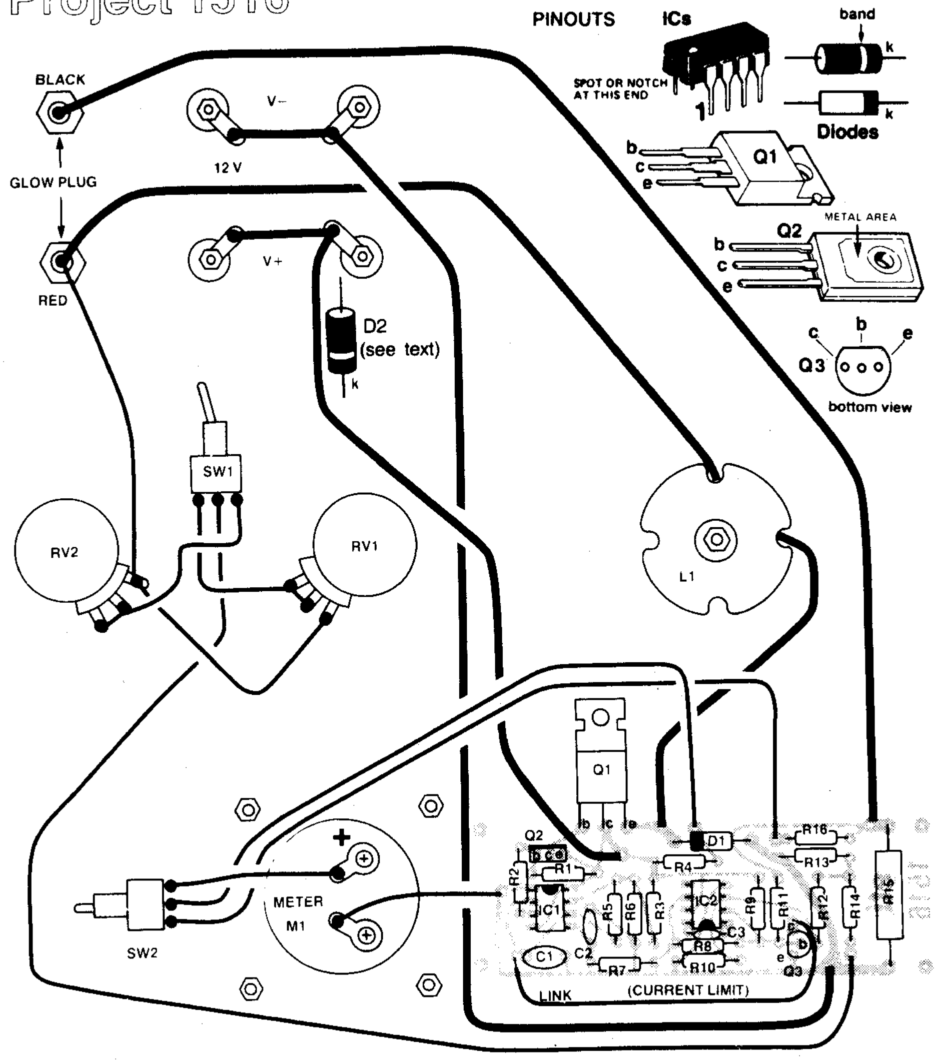


Figure 1.



Component overlay and wiring diagram. General wiring diagram and pc board assembly. Note that SW2 is a pushbutton switch. Push in to read voltage.

Components & Kits

Suppliers of components and kits for this project are listed in the 'Shoparound' page in this issue. ETI does not sell kits or components for projects.

PARTS LIST — ETI-1516

Resistors	all ½ W, 5% unless noted
R1, 2, 11, 12	1k
R3	6k8
R4	15k
R5	3k3
R6	18k
R7	100R
R8, R10	150k
R9	4M7
R13	120R
R14	33R
R15	0R12, 5 W
R16	**560R**
RV1, RV2	500R preset or panel mount type pots
Capacitors	
C1	47n greencap
C2	10n greencap
C3	1n greencap
Semiconductors	
D1	3 A or 5 A, 100 PIV (e.g: 1N5405 or 1N5408)
D2	EM401, EM402, 1N4001, 1N4002
IC1	uA555, NE555, LM555 etc
IC2	CA3140
Q1	MJE3055, TIP3055, 2N3055
Q2	BD140
Q3	BC548, BC108, DS548 etc
Miscellaneous	
L1	20 mH inductor, wound on FX2243 potcore assembly with 1.5 mm enamelled copper wire, 40 mm 4 BA bolt, nut and fibre washers
M1	1 mA meter movement; e.g: University TD48 or Minipa MU45.
SW1	SPDT or DPDT miniature toggle switch; e.g: D.S.E. S-1245 or similar.
SW2	SPDT or DPDT momentary action pushbutton; e.g: D.S.E. S-1220 or similar.

ETI-1516 pc board; banana sockets or polarised plug/socket; metalwork (see text); heavy duty hookup wire (24 x 0.2 mm or heavier); meter scale; terminals for plug cable termination; standoff pillars, nuts, bolts, wire, solder etc.

Price estimate $35 — $40

So, having settled for the option you wish, assemble the pc board components with particular attention to the IC polarity. Note that the two ICs are oriented oppositely to simplify the pc board pattern. There are no electrolytic (polarity conscious) capacitors specified. If you are far away from the battery you may find you need a 10 uf/16 V tantalum capacitor across the supply terminals, but my prototype was quite happy without one. Check the board when you've finished it.

The last stage of assembly is to fit the pc board and run the interconnecting wires. Be sure to use heavy gauge hookup or automotive wire for the connections to L1, the supply, D1 and the glow plug current loop. Fit Q1 to its heatsink using some thermal compound. Use an insulating washer if you are fitting it to the panel as a heatsink. Be sure to remove any burrs from the mounting holes which might prevent close mating of the transistor and heatsink, or puncture the washer if used.

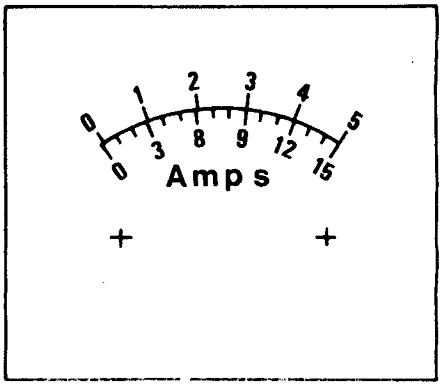
My prototypes used the least reliable option in each of the above cases, to prove that the unit could work that way: small heatsink on Q1, 3 A diode for D1, a diode in place for D2, no capacitor on the supply and the whole thing inside a jiffy box.

After five minutes of heavy work (at 3 A) I had to turn it off to prevent Q1 failing, but all else worked.

If you are not skimping we think that you should use a large heatsink on Q1 and perhaps a capacitor on the supply terminals if you are not sure what leads will be used in the field. The other construction suggestions will all aid reliability also.

The second unit tested used the tent-shaped metalwork and Q1 was bolted to the rear panel. This will run indefinitely without sign of failure.

Once construction is completed, check it over thoroughly. When you're satisfied all's well, apply power and listen carefully before connecting up the glow plug. The inductor is almost certain to emit a 'singing' noise as the switcher idles along. Short the output and the current meter will respond with about 4½ amps and the singing note will change. This indicates normal operation.



Meter scale. Full size reproduction of the meter scale. For those who want to make their own from Scotchcal, a same-size negative or positive transparency can be had for $1 post paid from: **ETI-1516 Artwork, ETI Magazine, P.O. Box 21, Waterloo NSW 2017.** Make cheque or money order payable to 'ETI Artwork Sales'. Ensure you ask for a **positive** or **negative** according to your requirements.

Using it

In practice, nothing could be simpler than this device to use. Ideally, you should set the temperature control while viewing the glow plug removed from the head of the engine.

Connect a 12 V battery to the input of the unit. Remove the glow plug from the engine head. Reduce the selected temperature pot. to minimum resistance and connect the glow plug to the output terminals. Slowly bring the temperature up by adjusting the pot. *away* from the minimum resistance end of its travel (rotate clockwise). The plug coil will begin to glow.

Clearly, if you bring the temperature up too far you will burn the plug out, so be careful. A glow just beyond red is best, just tending to orange. If you are in doubt, it is best to try a lower setting and go up later.

You can set one pot. for red-orange plug coil and the other for orange-white, using this higher setting by flipping the temperature select switch if the lower setting will not effect motor starting.

Once you have seen the level which causes no starting problems it is simple to set up all further plugs in a like manner.

Once the plug is reinstalled in the head you should proceed to start the engine in the usual manner as recommended by the manufacturer. Because of the temperature regulating action of the controller you will find it much more difficult to foul the plug or flood the engine.

Any foreign matter in the glow plug fitting tends to cool the element and so elicit an increase in the power delivered, burning the extraneous stuff off quickly. The current limit mechanism prevents plug failures due to one part of the coil cooling and producing higher currents while another part of the coil is uncooled and overstressed.

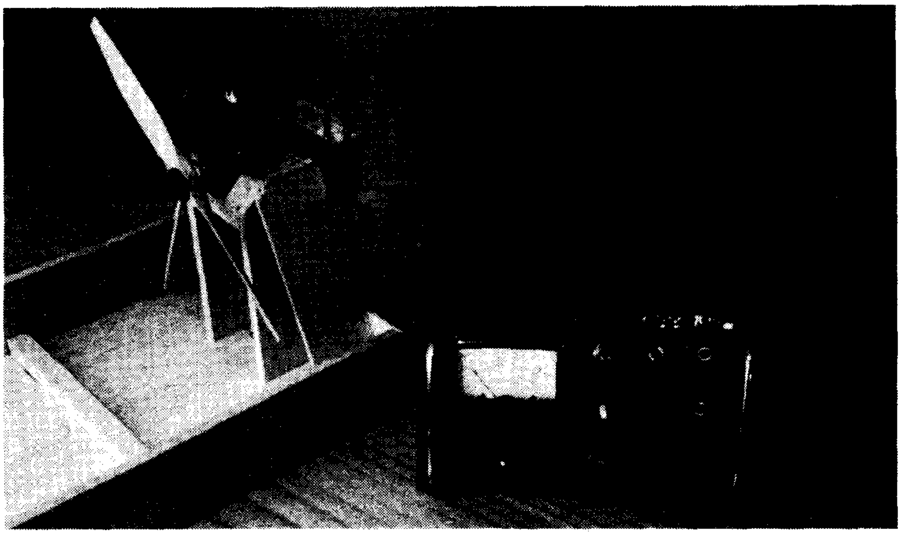
You will also notice certain other effects. When coming close to starting by firing on the first compression stroke, but not further ones, the current needle will be seen to dip momentarily. This is on account of the heat produced by the single ignition, which heats the plug somewhat, reducing in turn the need for the controller to supply heat to keep the coil up to the commanded temperature.

On the other hand, too rich a fuel mixture or tendency to flood will be evidenced as the reverse; momentary rises in the current delivered to the plug indicate that the coil has been splashed or otherwise cooled, necessitating a moment of boost. (You may feel free to consider at these moments how another system would be labouring to boil off the contaminant).

Again, when the engine has started there will be a significant fall in current, simply because the repeated combustion explosions in the head are doing most of the heating of the glow plug.

Other non-temperature sensitive systems would tend to overload the glow plug at this point, a fact that was only brought to our attention by the observation of the power drop upon starting.

One final note: The ETI-1516 may seem like overkill to some, realising that there would be significant feedback action if the glow plug were merely connected to a sound voltage regulated output, (preferably with remote sensing to eliminate the constant resistances of wires and so forth) by virtue of the sharply non-linear nature of the temperature/resistance characteristic.



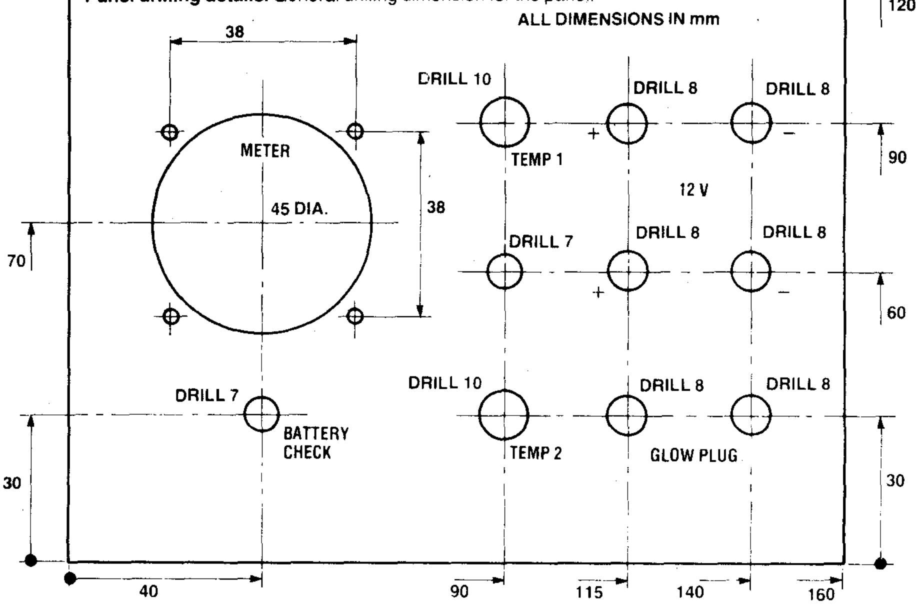
Tent model. This is the tent-shaped model I built. The wiring diagram on the previous page shows the physical layout of the rear panel of this unit.

This is indeed true, but the complexity of a current-limited switchmode voltage supply falls short of the complexity of the system here by only such a small margin that it turns out not to really be worth it.

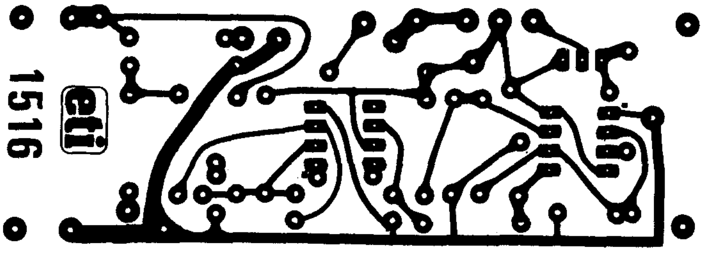
One could save the odd few resistors and a diode or so, but it would require all the major semiconducting elements with which we have managed to achieve temperature regulation merely to provide a sharp low impedance source, so why not go the whole hog, so to speak?

May your starts be many, now that they're virtually all 'sure starts'! ●

Panel drilling details. General drilling dimension for the panel.



Printed circuit artwork. Full-size layout of the pc board, copper side. A same-size positive or negative transparency can be had for $1 post paid from: **ETI-1516 Artwork, ETI Magazine, P.O. Box 21, Waterloo NSW 2017.** Make cheque or money order payable to 'ETI Artwork Sales'. Ensure you ask for a **positive** or **negative** as you require.



Project 1514a,b

Use these electronic switches to control things from your computer

Here are two 'electronic switches' which you can use to control mains-operated devices or appliances from your microcomputer. As opto-isolators are used, they allow safe interfacing directly from the computer or a controller board and can be driven over a simple two-wire cable for a considerable distance.

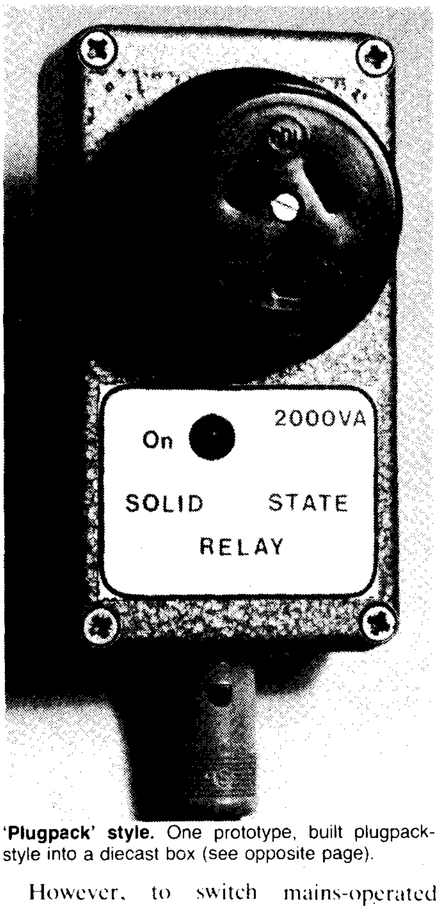
Graeme Teesdale

THERE COMES A TIME in every true-blue computer hobbyist's life when he/she wants to use the computer to actually *control* something in *the real world.* Like, turning lights on and off, or motors, etc. It's an understandable ambition. A computer which draws clever pictures on a video screen and dumps messages on a printer is pretty well a self-sufficient machine, only interacting with the real world via its benevolent operator.

'Ports', that is, a connection into or out of a computer, have been provided on most microcomputers released in recent years. While generally used to communicate with printers, modems and other peripheral devices, a port can be used to *control* things that are electrically operated — like lights, motors, etc, as suggested before. However, the circuitry in a computer which 'drives' an output port is generally not capable of switching substantial currents or voltages, not even the current required by a small relay, so some means of switching larger currents form the signals available on the lines of a port is necessary. For that, an 'electronic switch' can be used.

A 16-channel computer output driver was described by Geoff Nicholls in the November '82 issue of ETI, Project 653. It employed transistor output switches capable of 'sinking' or switching currents up to three amps and was designed to connect to a computer 'expansion' port where the address and data buss lines are brought out.

From feedback, 16 channels was up to a dozen too many and switching ac-operated (particularly mains-operated) devices was not possible, except via a suitable relay. In addition, the use of a computer parallel port, which can be readily driven from BASIC, such as on the popular Microbee, was deemed desirable.



'Plugpack' style. One prototype, built plugpack-style into a diecast box (see opposite page).

However, to switch mains-operated devices, it is *essential* to have adequate isolation between the mains and the computer. In addition, the controlled device and the computer may be located a long way from one another and long wires are susceptible to picking up interference which can cause spurious operations you didn't plan on.

These requirements can generally be met by one simple electronic device — the *opto-isolator.*

For a lot of applications, and particularly where absolute 'fail safe' operation is not required (e.g: switching lamps), electromechanical relays can be replaced by a solid-state switch — a triac or SCR. They can be used in ac or dc circuits, but in ac applications solid-state switches come in two types:

(i) zero crossing switch action, and
(ii) non-zero crossing.

The zero crossing type turns on or off *only* when the ac voltage is passing through zero, regardless on what part of the ac cycle the electronic switch is activated. This prevents the 'commutation', or switching, interference generated by the high in-rush currents that may be generated when an SCR or triac is turned on during a part of the cycle when the ac voltage is substantial.

One of the problems with zero crossing electronic switches however, is that, in most designs, the switching device (e.g: a triac) is given a short duration positive- or negative-going pulse *just after* the ac voltage passes through zero. When inductive loads are used (e.g: a motor), the current often fails to reach the minimum 'latching' current required by the switching device before the pulse disappears. Most triacs are also generally not symmetrical in their gate trigger requirements and a positive trigger during the negative half of the ac cycle is often less sensitive compared to a positive trigger during the positive half of the ac cycle.

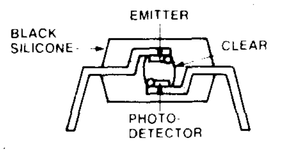
OPTOCOUPLERS

Optocouplers use a beam of infrared radiation (or occasionally, visible light) to convey the signal from one part of the circuit to the other without any electrical connection whatsoever between the two parts. They are sometimes known as *photon-coupled devices* or as *opto-isolators*. They may be employed to replace conventional relays when a fast response is required or when sparking at relay contacts must be avoided.

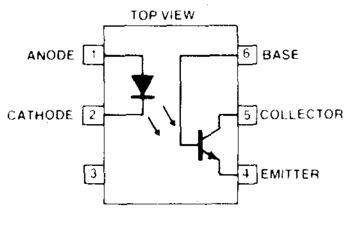
An optocoupling device consists of an infrared emitting device or other photon emitter on its input side and some form of detector for the radiation on the output side, both the emitter and detector being in a light-tight enclosure.

The silicon detector itself may be a photo-transistor, a photo-Darlington device, an opto-triggered triac or SCR, or even a field effect phototransistor.

No matter which of these device types is employed, the silicon detector has its maximum sensitivity at a wavelength quite near to that at which the gallium arsenide photon emitter device emits with its maximum intensity. In other words, the devices are spectrally well matched so that a small emitter device current can produce a reasonably large response in the detecting device.



Cross-section through an optocoupler.



Pinout for the 4N26 – 4N28 and MCT2 devices.

Although some optocoupled devices are fabricated in circular metal packages, the most common types are produced in dual-in-line (DIL) packages with a typical construction like that shown in the diagram. The emitter and detector are placed fairly close together with a clear insulating material between them. The black silicone body of the device prevents stray radiation from falling on the detector.

In most DIL devices the radiating emitter is connected to pins on one side of the device while the detector is connected to pins on the other side. This arrangement provides the maximum possible electrical isolation between the input and output circuits. Many of the simpler optocoupled devices differ from most other dual-in-line devices in that they have a total of only six connecting pins.

The basic internal circuitry of the 4N26, 4N27, 4N28 and MCT2, with a single phototransistor output, all have the connections shown in the pinout diagram here.

Two designs

As there are applications where a zero crossing switch is unnecessary or unusable (e.g: switching dc-operated devices) I have designed electronic switches of each type. Both designs make use of opto-isolators (or optocouplers) to isolate the microcomputer from the power source being switched — which will generally be the 240 Vac mains. The optocoupler's transparent dielectric provides an isolation between input and output terminals of up to several thousand volts, depending on the type used. The other advantage offered by an optocoupler is that the use of a LED for the photon emitter creates a 20 mA loop. The driver for the LED input of the photocoupler is located at the computer rather than the solid-state switch and the effects of noise induced into the cable will be considerably less for a 20 mA low impedance circuit than the relatively high impedance loop of a logic device or transistor base. A lot of interference noise comes from external leads running back inside the computer's case and re-radiating noise into the data, address and control lines. A low impedence 20 mA loop substantially reduces or eliminates this problem.

The non-zero crossing switch is designated ETI-1514a, the zero crossing switch being ETI-1514b. Each has the same basic mechanical design so that either can be used interchangeably in a case or chassis drilled accordingly.

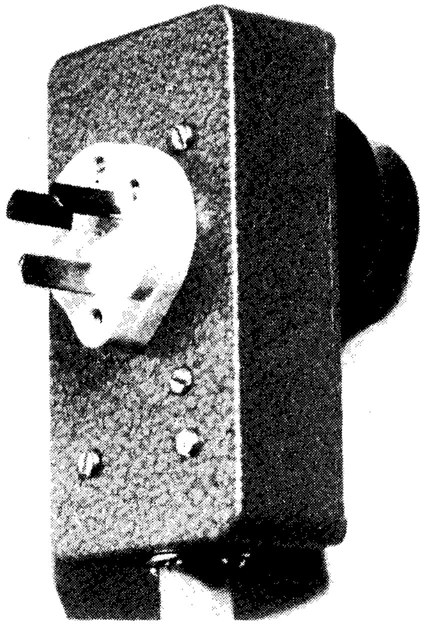
If your computer has an eight-bit parallel port, then up to eight switches can be controlled from it. The ETI-673 Microbee MultiPROM Interface board features 11 output lines and these electronic switches are ideal for controlling mains-operated devices via this board.

I have designed each switch so that the input is not polarised. That is, *it doesn't matter which way round you connect the two wires*. One goes to the computer output port line, the other to common (or 0 V) for *active-high* outputs or the positive supply for *active-low* outputs.

To cover the widest possible range of applications, I chose a common triac rated at 16 amps/400 V — the RCA type T6000D. The continuous current rating of ordinary mains outlets is 10 amps, so it is adequately rated for mains-operated devices or appliances. However, if you happen to operate an ac device from a lower voltage, via a transformer for example, then you may need the higher current capability. The T6000 triac is rated to withstand peak surge full-cycle currents of 150 amps.

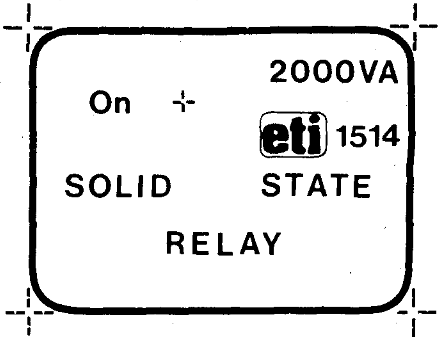
For the zero crossing switch, I chose an IC specially made for this application — the TDA1024. It is cheap (around $3) and generally readily available. It will happily drive the T6000 triac. RCA make the T6006 triac specifically for zero crossing switch applications, but I found it not so easy to get as the T6000. As the TDA1024-T6000 combination seems to operate reliably, why worry? Other triacs, such as the SC141 — a 6 A/400 V device, can be used also if you don't require the 16 A rating of the T6000.

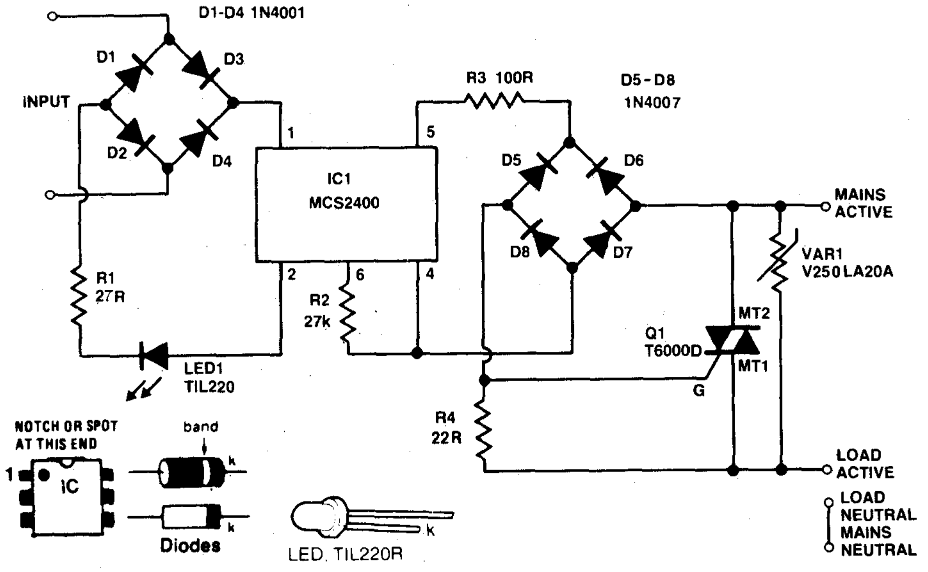
The TDA1024 provides a positive-going mains-synchronised trigger pulse for the triac whenever its control input is activated. Since the current and voltage in the load must be in phase for mains-synchronised switching, only resistive (or substantially resistive) loads can be attached to the ETI-1514b zero crossing switch. Incandescent lamps and heater elements are substantially resistive and the ETI-1514b can be used on these loads, but not on reactive loads such as a motor — that's why the non-zero crossing switch, ETI-1514a, is used. ▶



Rear view. Showing plug mounting.

Front panel. Full-size panel artwork.





PARTS LIST ETI-1514A
non-zero crossing type

Resistors	all ½W, 5% unless noted
R1	27R
R2	27k
R3	100R
R4	22R
Semiconductors	
D1-D8	1N4007, EM410
LED1	TIL220R red LED
Q1	T6000D triac
IC1	MCS2400 optocoupler
Miscellaneous	
SK1	5-pin DIN socket
PL1	5-pin DIN plug
VAR1	Varistor, G.E. type V250LA20A

ETI-1514A pc board; diecast box to suit (see text); 240 Vac 3-pin surface socket; 240 Vac 3-pin plug (see text); aluminium angle bracket (see text); wire, nuts, bolts etc.

Price estimate: $22-$26

HOW IT WORKS — ETI 1514a

This is the non-zero crossing switch which is suitable for both reactive and resistive loads (e.g: motors or lamps, respectively). However, commutation interference is generated with reactive loads and the use of a line filter between the unit's mains input and the mains is recommended.

The input signal from the computer turns on the photon emitter in the optocoupler which in turn triggers the triac which turns on, supplying current to the load during both positive and negative half cycles of the ac mains cycle.

The optocoupler used here, a type MCS2400 by G.I., features a photo-SCR output. This was chosen mainly for its better dv/dt capability over the photo-triac output types, such as the MOC3020.

For full-wave ac control using the MCS2400, it is necessary to use a diode bridge in the triac trigger circuit. This bridge is provided by diodes D5-D8 here. Resistor R3 provides surge current limiting and keeps gate currents to the triac to safe limits. Resistor R2 is included to render the photo-SCR in IC1 insensitive to rapidly rising voltages across the junction or isolation capacitances of the diodes in D5-D8 bridge, and insensitive also to currents generated by leakages and discharges of stored charge during turn-off. The selection of R2 is a compromise between the minimum current required by the input photon emitter and the photo-SCR being completely immune to dv/dt and other extraneous effects. I found the value of 27k to be a good compromise.

Resistor R4 shunts di/dt currents passing through the D5-D8 bridge diode capacitances from the triac gate.

Voltage transients that might destroy the triac are 'snubbed' by a metal oxide varistor, VAR1 — a V250LA20A MOV II type by General Electric. This type of device provides far more protection than can be achieved by using the traditional series-RC network. The varistor will 'switch on' when a transient exceeds its rated peak voltage, acting rather like back-to-back zeners, and offering a very low impedance path to the transient. It is connected in parallel with the triac here.

The V250LA20A is capable of handling a transient peak current of 4500 A for a duration not exceeding 20μs. Its energy rating is 72 joules, dc switching voltage 330 V. Varistors do not require discharging by the triac, as is the case with a series-RC network.

So that the switch's input circuit need not be polarised, making it more versatile, I have added a diode bridge to 'steer' the input current correctly, regardless of polarity.

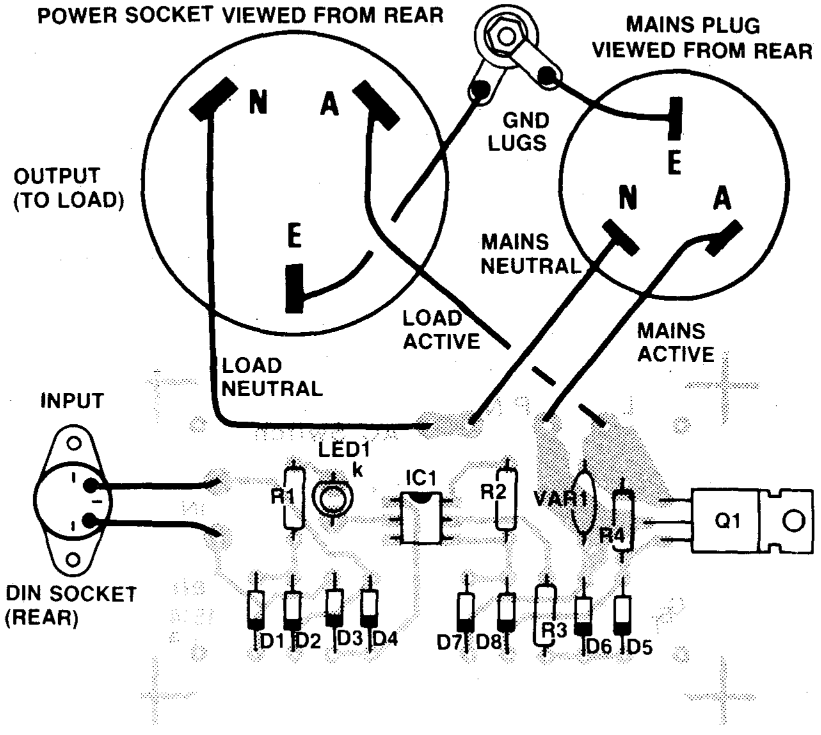
In series with the optocoupler's photon emitter input I have added a LED to indicate the 'on' condition. Resistor R1 acts as a current limiter. If the unit is to operate from a source providing greater than 5 V drive level, it is only necessary to increase the value of R1 to limit the input circuit current to around 15-20 mA.

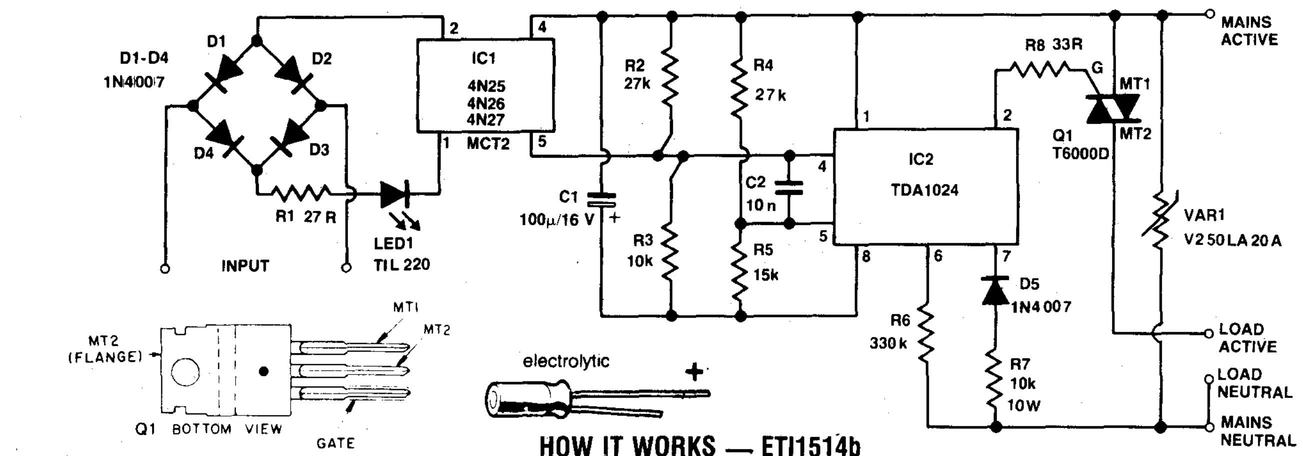
Construction

The two pc boards have mechanically similar layouts, as can be seen from the photographs and overlay diagrams. The board for the zero crossing switch, ETI-1514b, is slightly larger. The triac on both is located on one end with he input and indicator LED at the opposite end, keeping them well separated from the mains wiring.

I mounted the prototype ETI-1514b in a small aluminium diecast box which I turned into a type of plugpack using a right-angle type power plug attached to the rear and a surface-mount mains socket attached to the lid, as can be seen in the photographs. A scrap of aluminium bent up as a bracket was used to provide both a heatsink and mounting for the triac. Note that the triac's metal tag *has to be insulated* using a mica washer and insulating bushes. For safety's sake, the case is earthed. I haven't given drilling details as this is simply one suggested form of construction and many variations are possible.

The board could be mounted in the equipment being controlled, for example, or a number of boards could be mounted in





HOW IT WORKS — ETI1514b

This is the zero crossing switch. It can only be used on resistive (or substantially so) loads as mains-synchronous switching is employed.

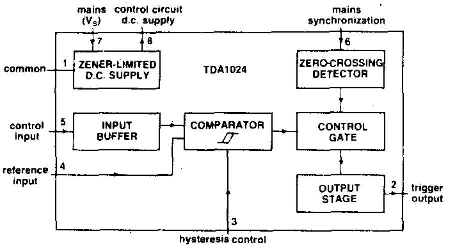
In this unit, the input signal from the computer turns on the photon emitter in the optocoupler (IC1), the output of which activates the control input of the zero crossing driver, IC2. When the mains voltage passes through zero, the trigger output of IC2 turns the triac on, supplying current to the load during both positive and negative half cycles of the ac mains cycle.

In this unit, like the ETI-1514a, the input circuit employs a diode bridge, D1-D4, so that the input need not be polarised. A LED in series with the optocoupler's photon emitter indicates the 'on' state, R1 providing current limiting.

The optocoupler used here has a transistor output and a number of types can be used — such as 4N25, 4N26, MCT2 etc.

The TDA1024 (IC2) zero crossing switch IC is designed to derive its own supply from the mains and can drive a medium-sized triac from its trigger output.

A block diagram of the TDA1024 is shown. The comparator features Schmitt-trigger action and compares the control voltage at pin 5 with the reference voltage at pin 4 and switches on when the control voltage exceeds the reference voltage. The comparator hysteresis is adjustable between 20-300 mV by selection of the resistor value connected between pins 3 and 1. Hysteresis is minimum with pin 3 open, so I have left it open.



An external series dropping resistor (R7 here) is needed to limit the repetitive peak in-rush current to the IC's internal zener supply to less than 80 mA. In fact, average current is approximately 10 mA. Diode D5 is added in series with pin 7 to 'block' the negative half cycle of the input, reducing the dissipation in R7 to half what it would otherwise be. When D5 is conducting, it charges C1 up to the stabilising voltage of the internal zener. The voltage between pins 1 and 8 should be no greater than eight volts. Any excess current is bypassed by the internal zener. Pin 6 is connected through R6 to the mains, providing the synchronising signal and, in addition, trigger pulse width control. With the value of R6 at 330k, the output pulse width to Q1 is about 125 µs. This can be increased by increasing the value of R6. The maximum rated trigger output current of 100 µA is obtained with a trigger pulse width of approximately 260 µs.

The trigger output of IC2 (pin 2), is an open emitter capable of sourcing a maximum of 100 mA, as stated above, and this is internally current-limited for protection against short circuiting. The output pulse amplitude is stabilised at 4 V for trigger currents up to the maximum value.

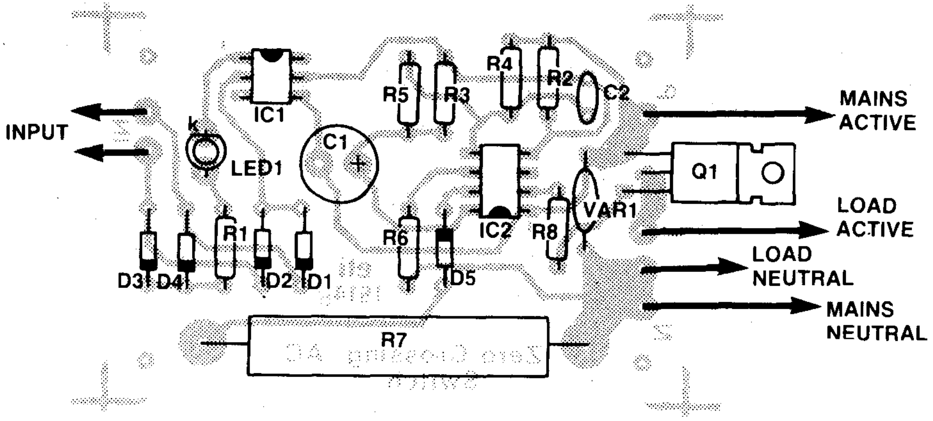
The series resistor must be connected between the trigger output of IC2 and the gate of Q1 to limit the trigger current. Resistor R8 was chosen to limit the output current to about 10 mA average.

When the voltage on pin 5 exceeds that on pin 4 (with respect to pin 1), and the sinusoidal voltage applied to pin 6 passes through zero, the comparator will switch, operating the control gate, triggering the output stage and a trigger pulse will be supplied to the gate of Q1 from pin 2 of IC2. When an input signal is applied to IC1, its output (pins 4-5) shorts R2, dropping the voltage on pin 4 of IC2 below that on pin 5, effecting a trigger.

For transient protection, a varistor is used in this unit too. Here, however, it is connected directly across the mains input to absorb mains-borne transients. As the load is turned on and off at zero voltage, 'snubbing' across the triac is unnecessary.

a suitable box and mains outlet sockets provided for connection to the controlled devices, etc. The details will depend on your individual application. However, always make sure the mains wiring is properly terminated and installed in a workmanlike fashion. All exposed metal parts *must* be connected to the mains earth. Take care with active and neutral wiring. Don't mix them up.

Board assembly is straightforward. Always check the pc board before commencing assembly to see that all the holes are correctly drilled and that there are no tiny copper 'bridges' between closely-spaced track, particularly between IC pins. There is no particular order of construction. However, make *double sure* you get semiconductors and polarised capacitors (C1 in the zero crossing switch) the right way round. ▶



ETI-1514B zero crossing type

Resistors	all ½W, 5% unless noted
R1	27R
R2, R4	27k
R3	10k
R5	15k
R6	330k
R7	10k, 10W
R8	33R
Capacitors	
C1	100µ/16 V single-ended electro.
C2	10n/50 V ceramic or greencap
Semiconductors	
D1-D5	1N4007, EM410
LED1	TIL220R
IC1	4N27 or sim. optocoupler
IC2	TDA1024 zero-crossing switch
Q1	T6000D triac
Miscellaneous	
VAR1	Varistor, G.E. type V250LA20A

ETI-1514B pc board; other parts as per ETI-1514A.

Price estimate: $24-$28

In use

The switches require a 5 V-level input, capable of sourcing around 15 to 20 mA. For example, say you attached one of these switches to an output line of the ETI-673 Microbee MultiPROM Interface board. One of the switch's input wires would go to the +5 V supply (pin 12 of the '673's I/O socket, SK1), the other wire would go to the appropriate output line pin. The ETI-514 switch would then be activated when that particular output line was programmed on. Simple, what?

Where the input of a '1514 switch is driven from a 5 V-level output and extra interference protection is required, as might be necessary when running the switch's input cable over very long distances, a varistor can be added across the line where it attaches to the computer or interface. The General Electric type no. V8ZA2 would be suitable in such applications.

Where long cable runs between the switch are necessary, use a medium to heavy duty 'figure-8' cable to keep resistive voltage drop along the cable low. Shielded twin-pair cable can be used, but ground the shield only at the computer or interface end, not at the '1514 switch end.

When installing a '1514 board, always run the mains leads *directly away* from the input leads so as to minimise possible interfence being induced into the input circuitry. ●

ZERO-CROSSING AC SWITCHING

There are two basic ways of switching mains power to a load — either via a mechanical switch or via a solid-state switch such as a triac. Mechanical switches are fairly slow-acting devices; they suffer from severe arcing at the moment of switching and generate a great deal of RFI (radio frequency interference) at switch-on and switch-off. This RFI can often be heard on domestic radio and TV sets and can cause malfunctioning of some electronic equipment (particularly digital equipment).

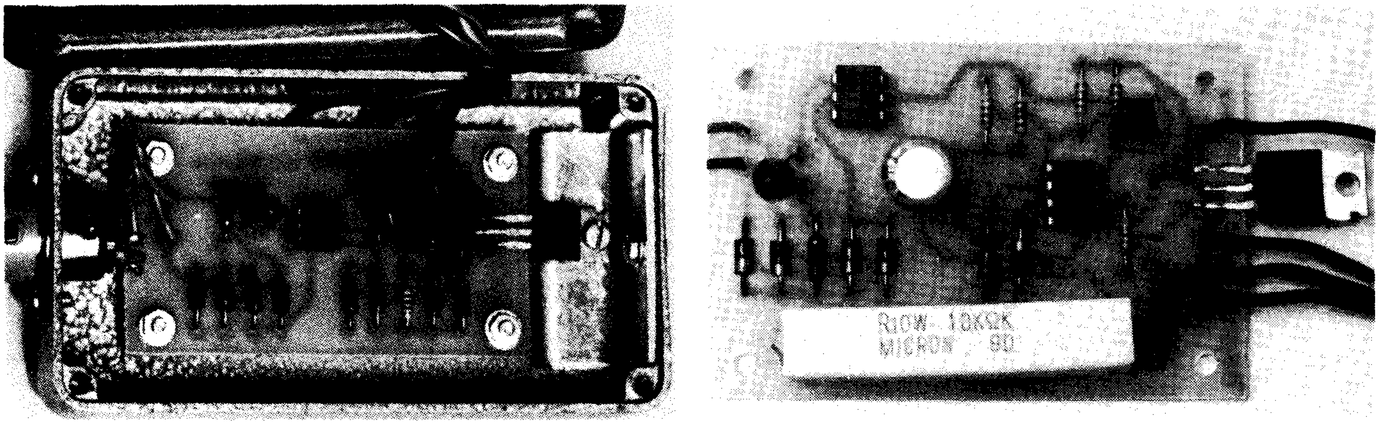
Triac switches are fast-acting devices and do not suffer from arcing problems. Nevertheless, they are still capable of generating considerable RFI at switch-on. Why? As the triac turns on, the load current may rise from zero to several amps in a mere couple of microseconds; since this current flows through the mains wiring, the wiring may radiate a great 'splurge' of RFI in response to this heavy surge current.

The magnitude of the RFI is proportional to $\delta i/\delta t$ and can be reduced by either reducing the surge current amplitude or increasing the surge current rise time, or possibly both; once the triac has turned on, the subsequent large 'rise time' of the 50 Hz mains signal (5 ms from zero to peak) causes virtually zero RFI, even when load currents of tens of amps are being drawn.

Thus the degree of triac switch-on RFI is proportional to the value of instantaneous mains voltage at the moment of triac turn-on. If a 100 ohm load is being driven from 240 Vac mains, the surge current will be 3.4 A if switch-on occurs at a 'crest' value of 340 V, or a mere 3.4 mA if switch-on occurs at a 'near zero crossover' value of 3.4 V.

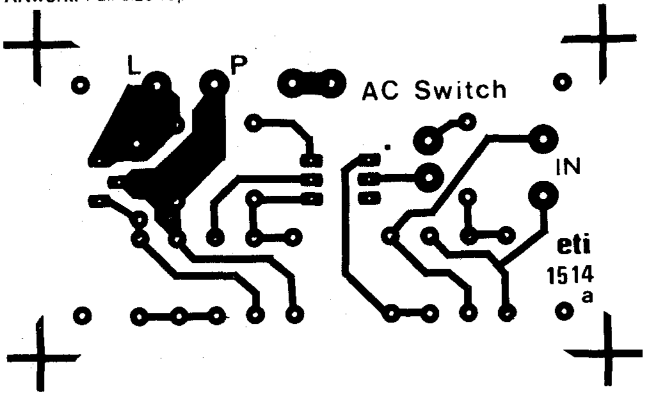
Triacs are self-latching devices. If they are turned on by a brief gate signal, they remain on until their main-terminal (MT1-MT2) currents fall below a minimum 'holding' value of a few milliamps. They automatically turn off at the end of each mains half cycle as their main-terminal currents fall to near-zero. They can be turned on near the start of each half cycle as soon as their main-terminal currents are capable of exceeding the minimum holding value.

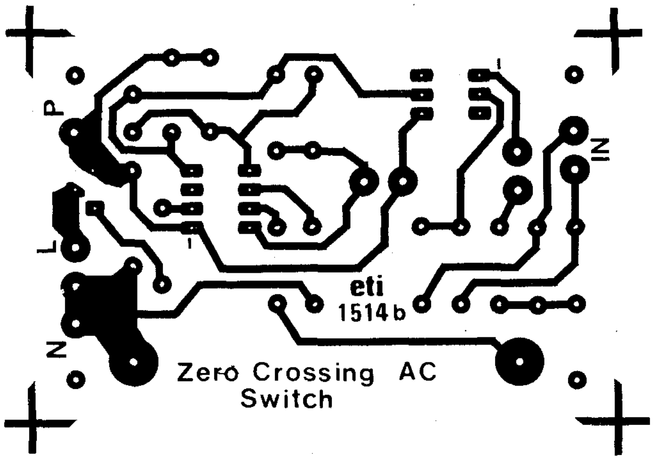
Thus, a triac can be persuaded to generate virtually zero switch-on RFI by feeding it with gate current *only* when the instantaneous mains voltage is close to the zero or crossover value at the start of each half cycle. This technique is known as 'zero crossing switching'. Special triac-driving ICs are available from a number of manufacturers for zero crossing switching applications, such as the CA3059 by RCA and the TDA1024 by Philips/Signetics.



Inside story. Showing how the ETI-1514a was mounted in the plugpack-style diecast box. The ETI-1514b board is shown at right (note that the varistor was not mounted when the picture was taken).

Artwork. Full-size reproductions of both boards.





For tennis players — an electronic 'let' caller

This low cost, simple to build project detects when a ball 'tips' the net cord as it passes over — no more disputes about whether it did or it didn't! No false alarms either.

Geoff Nicholls

TENNIS IS a popular outdoor sport, particularly in summer. But a 'friendly' game can be spoilt by bad feelings arising from a dispute — particularly where a 'let' call is involved, where the ball is seen to 'tip' the net cord wire as it passes from one side of the court to the other. This little project will solve such disputes and is safe from 'human fallibility', provided it is correctly set up — a simple procedure.

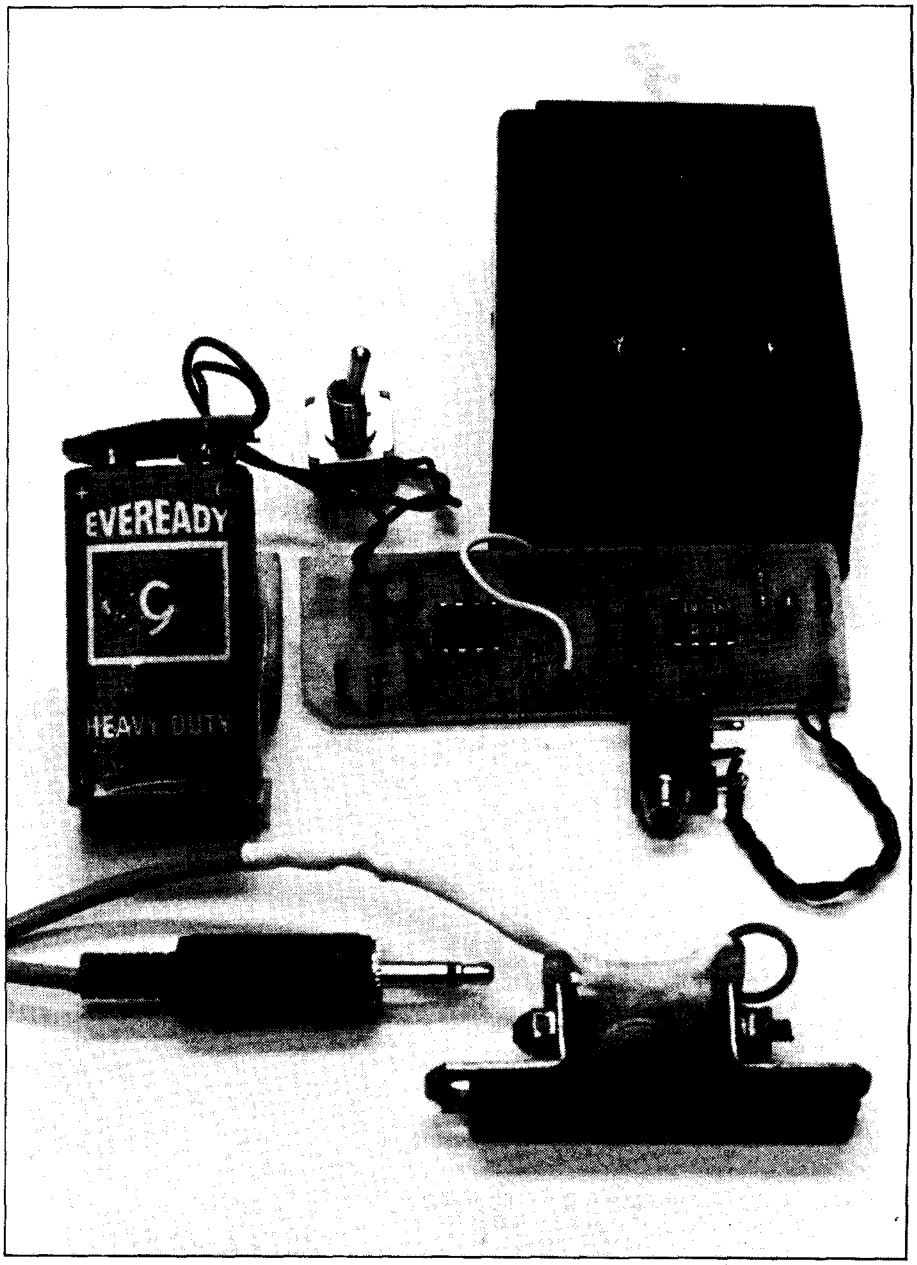
When I first thought of this project, I realised some sort of sensor and detection system that was free from false alarms would be necessary. This ruled out using a microphone attached to the net cord. As net cords are (usually) steel, I hit upon the idea of using some sort of magnetic sensor. It was obvious that trying to slip a coil over the net cord was out of the question, so some other scheme had to be devised. Then again, winding coils is tedious, so a ready-wound coil of some description was necessary. Casting around for something suitable we discovered reed relay coils were cheap and readily available, so I did some experiments to see if one could be pressed into service. It worked!

Thus, the sensor consists of, simply, a reed relay coil, a few brackets and a small bar magnet. This assembly is attached to the steel net cord, as shown in the accompanying diagram. When the ball strikes the net cord, a travelling wave moves out from the point struck by the ball, toward the net cord supports. The movement of the steel net cord in the magnetic field in the vicinity of the sensor coil causes a small variation in the magnetic field, inducing a voltage across the ends of the coil. This voltage pulse is detected and an alarm is sounded.

Construction

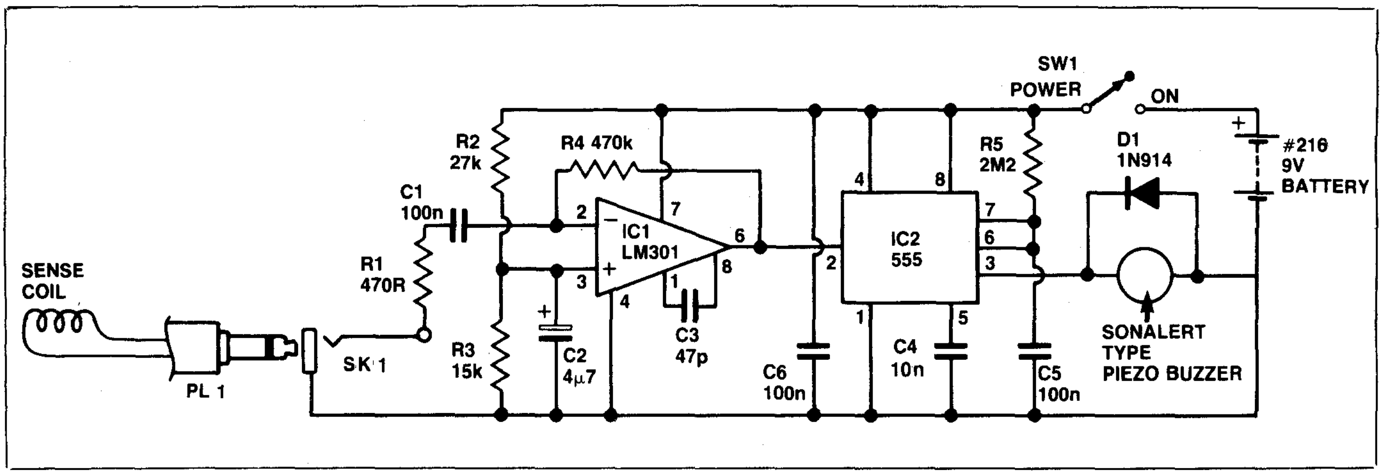
Everything except the sensor mounts in a small plastic box, the printed circuit board slots in to the grooves on the walls of the box with the 9 V battery on one side and space for the switch and sensor socket on the other side. The front panel is dressed up with a Scotchcal label.

The only unusual part of the project is the sensor, so I'll start with it. The heart of it is a reed relay coil, with a ⅛" (3 mm) steel screw down the middle clamping a small right angle steel bracket to each end. (See the accompanying photo). To create a good magnetic circuit I screwed two nuts up to



Neat and simple. All the bits for the Let Caller. There's not much to it, but it's certainly effective. The sensor coil is shown in the foreground. It mounts on the net cord (see diagram next page).

▶



the head end and put three nuts on the other end.

The sensor connects to the main unit via a 500 mm length of shielded cable, with a 70 mm length of 4 mm dia. heat-shrink tubing over the join. Secure the cable to the coil body with tape to relieve stress on the wires. Complete the sensor by soldering a 3.5 mm plug to the other end of the cable.

The Scotchcal label can be attached to the box lid now, the corner markers should be a few mm outside the lid area, so that they won't show when the label is trimmed. To get a good finish with a white background label I usually spray the lid with flat white paint and let it dry before sticking the label down. Once the label touches the lid it sticks fast, so it is important to carefully align it beforehand. Rub any trapped air pockets toward the edges and drill the holes for the switch and socket, then trim the four corner holes and lid edges with a sharp knife.

The piezo buzzer mounts on the plastic bottom of the box; the one I used required two holes in the box to pass the wires to its connecting pins. The buzzer easily attaches with double-sided adhesive tape.

Check that the pc board slots onto the box, trim by filing if necessary.

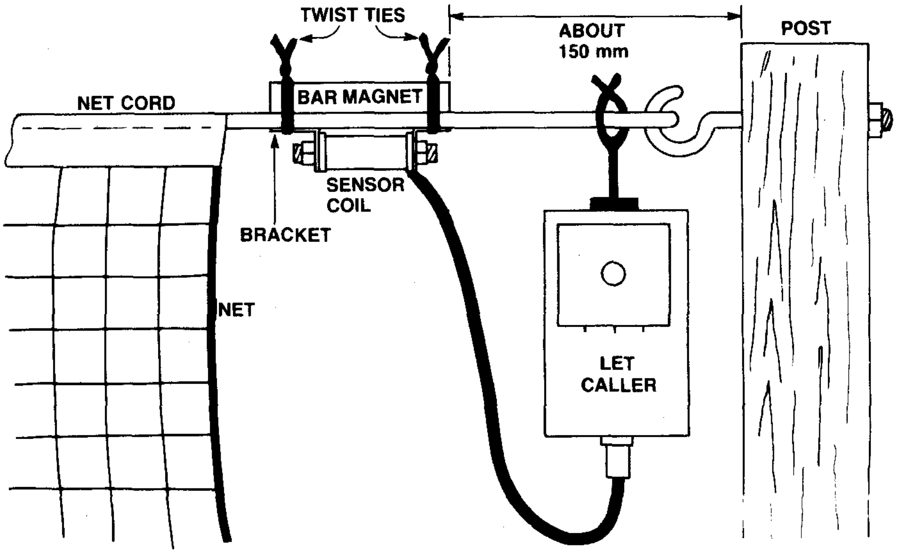
The pc board can be assembled now. The only point to watch is the orientation of the two ICs and the tantalum capacitor.

Solder a twisted pair of hookup wire between the pc board and the 3.5 mm socket, with 0 V going to the shield side. Complete the wiring to the battery and switch, then check that everything goes together. If the lid won't fit it is probably due to wires passing over the pc board. There are two solutions to this; either solder the offending wires to the copper side of the pc board or file an angle at the corner of the board for the wires to fit in.

The last thing to consider is how to attach the box and sensor to the tennis net. I used a plastic clip for the box called a Kurly-Lok On Base, Richco part no. KLB-750A. It is 40 mm high, has an adhesive base about 12 x 25 mm and is made by Richco, distributed here by Mayer Krieg & Co. You may be able to find another method of mounting but I bet it won't be as good as this curly clip which fits perfectly over the threaded rod used to tension the net.

The sensor and magnet work best when clamped onto the bare steel net wire about 150 mm from the post, with the wire between the two. I used wire ties as supplied with loaves of bread, although a clothes peg may be adapted to make it easier to attach.

The sensitivity is directly related to the strength of the magnetic field at the sensor coil. A small bar magnet is adequate, an old speaker magnet is superlative! (but probably 'overkill').



Installation. It's simple. Tie the sensor coil and magnet on the net cord about 150 mm from the post and hang the box near the post.

HOW IT WORKS — ETI-273

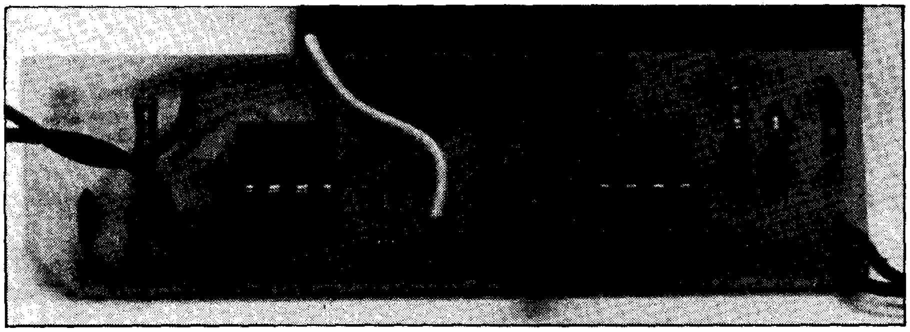
The sense coil is magnetically coupled to the net cord steel wire so that any change in the flux through the coil causes an induced voltage to appear across the coil.

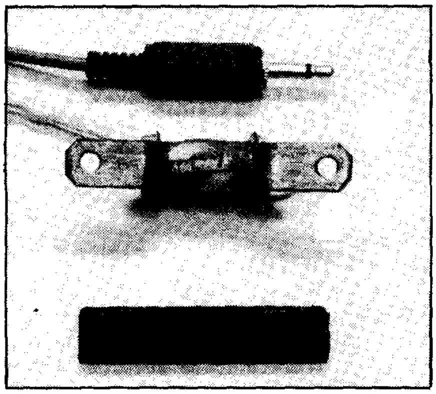
If the net wire is struck by the tennis ball the vibrations set up modulate the flux through the coil, thus producing an alternating voltage. This is amplified by IC1, an ac inverting amplifier designed with a gain of about 500 at 1 kHz, and a roll off of −20 dB per decade each side of that frequency.

Resistors R2 and R3 bias the amplifier's output to just over one-third of the supply voltage. C3 filters that bias voltage. IC2 is a 555 timer configured as a monostable multivibrator or one-shot with an interval of a quarter of a second.

When the voltage at the trigger input (pin 2) is less than one-third of the supply voltage, a timing interval is initiated, which sounds the piezoelectric buzzer. So any slight disturbance in the flux in the sense coil will cause the voltage at pin 2 of IC2 to drop below one third of the supply and activate the buzzer.

Diode D1 clamps any reverse voltage spikes from the buzzer, preventing false triggering.





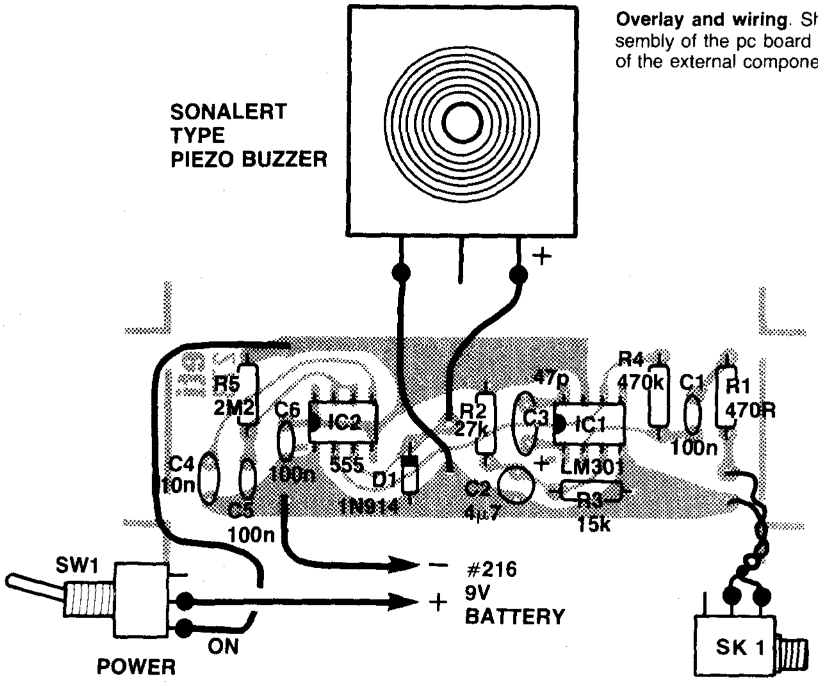
The bits. Above is a view of the completed pc board, below is a view of the completed sensor coil assembly.

Using it

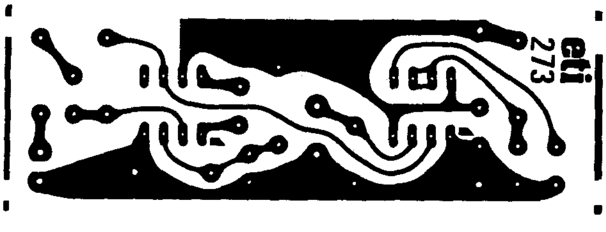
The Let Caller will beep once on power up, and may beep continuously if the sensor is not plugged in.

Since it responds to high frequency vibrations, a very slow serve may not 'twang' the net cord enough to trigger the unit, although I have used it for several hours and it never missed one. The wind doesn't seem to affect it either, and balls hit into the bottom of the net won't always trigger it. This confirms the validity of the sensor design and its superiority to a microphone-based system.

Having dispensed with the umpire, have a happy tennis game! ●



Overlay and wiring. Showing assembly of the pc board and wiring of the external components.



Board and panel. The pc board artwork is at left, panel artwork on the right. Both are shown full-size.

OTHER USES

The pc board could be used for a number of other purposes besides a Let Caller. For instance, the sense coil may be replaced by most transducers, as long as R4 was adjusted to suit the particular unit. The pulse length from IC2 can be increased by replacing C5 with a higher value tantalum capacitor. You could experiment and come up with a motor-bike alarm etc. The 555 IC can easily drive relays, so a high power load could be switched. The power supply can be anything up to 15 Vdc, so experimenters, go to it!

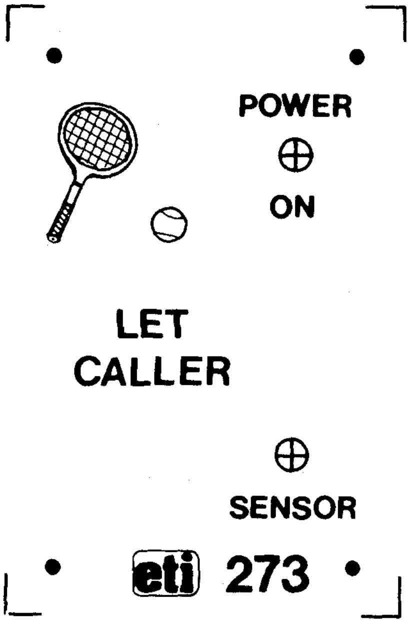
PARTS LIST — ETI-273

Resistors	all ¼W, 5%
R1	470R
R2	27k
R3	15k
R4	470k
R5	2M2
Capacitors	
C1, C5, C6	100n ceramic
C2	4µ7/35 V tant.
C3	47p disc ceramic
C4	10n ceramic or greencap
Semiconductors	
IC1	µA301, LM301, µA308, LM308
IC2	555 timer

Miscellaneous

ETI-273 pc board; Scotchcal front panel label; plastic 'zippy' box 80 x 50 x 30 mm; piezoelectric buzzer — Sonalert, Murata or similar; reedy relay coil — D.S.E. cat. no. S-1948 or similar; 3.5 mm plug and socket (optional); 500 mm shielded cable; type 216 9 V battery and snap connector; single-pole single-throw (SPST) miniature toggle switch;m two right angle steel brackets 12 x 12 mm; ⅛" x 2" Whitworth (3 mm x 50 mm) steel bolt and five nuts; curly-clip — Richco KLB750A or similar; 50 mm long bar magnet; double-sided stick tape; hookup wire etc.

Price estimate: $20-$24

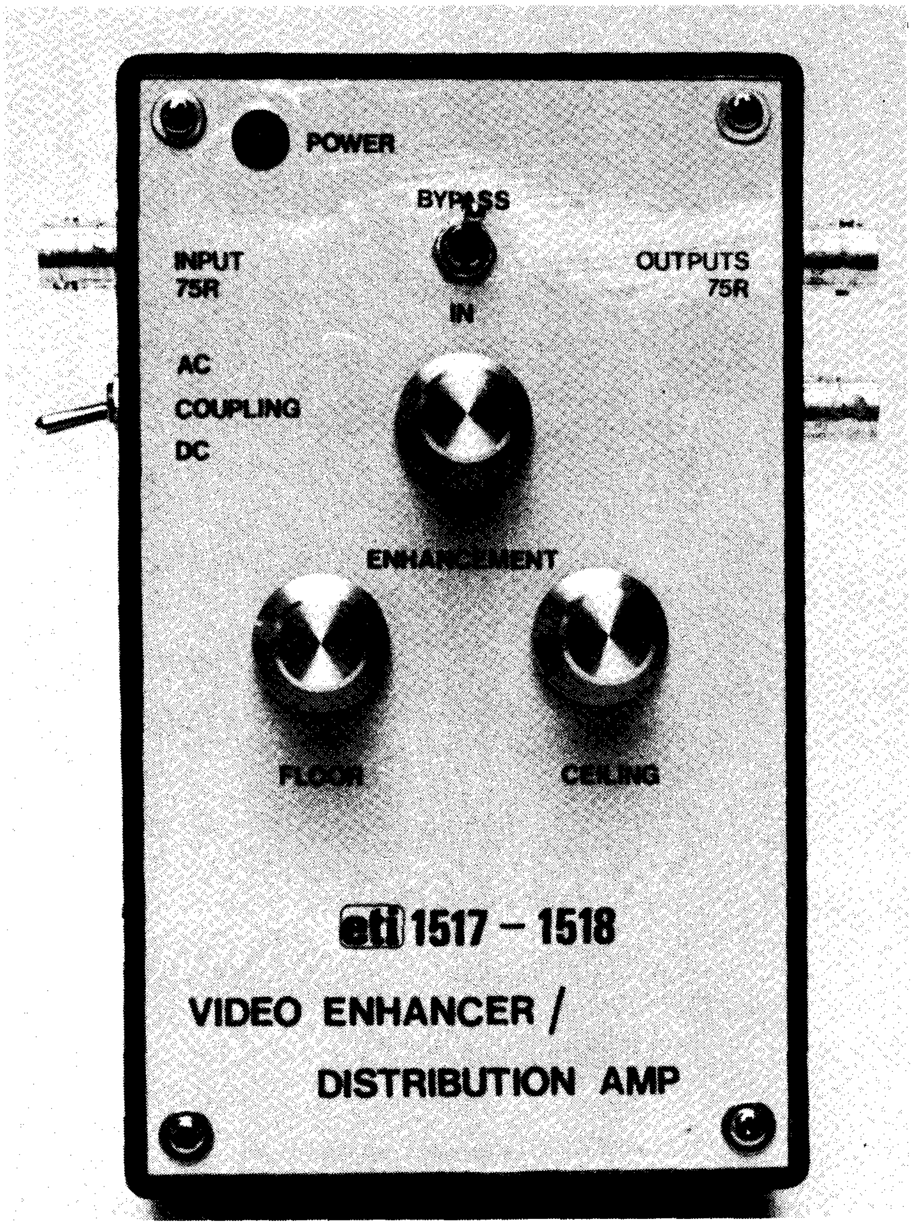


Project 1518

'Deluxe' video enhancer features three controls

This simple to build project features three controls for curing video 'image ills' — *floor* which cuts off the low-level noise that causes snow; *ceiling* — which ensures that high-level signals are not enhanced, causing ringing; and *enhancement*, which really 'crisps up' those soggy signals, providing up to 8 dB of boost.

John Power



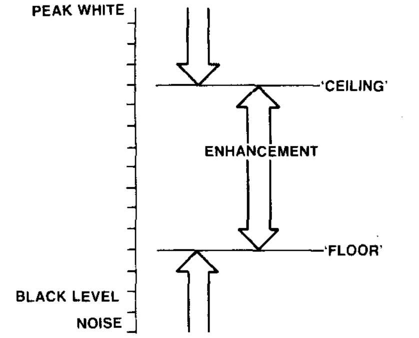
THIS PROJECT has been designed to team with the ETI-1517 Video Distribution Amplifier (page 101), but can be used 'stand alone' if you wish. It's easy to build, low in cost, and effective to use.

The problems one meets with video signals, particularly when recording and replaying, have been explained by Jonathan Scott in '*The ins and outs of video enhancers*', in ETI October '83. This project has been designed to avoid the problems that can arise in trying to compensate for video bandwidth degradation. I have included a 'notch' at the 4.43 MHz colour subcarrier so that it will not be 'enhanced' — to the detriment of the picture! — and have provided controls that set the limits of enhancement so that noise at one extreme, and high-level signals at the other, are not boosted, which can also further degrade a picture.

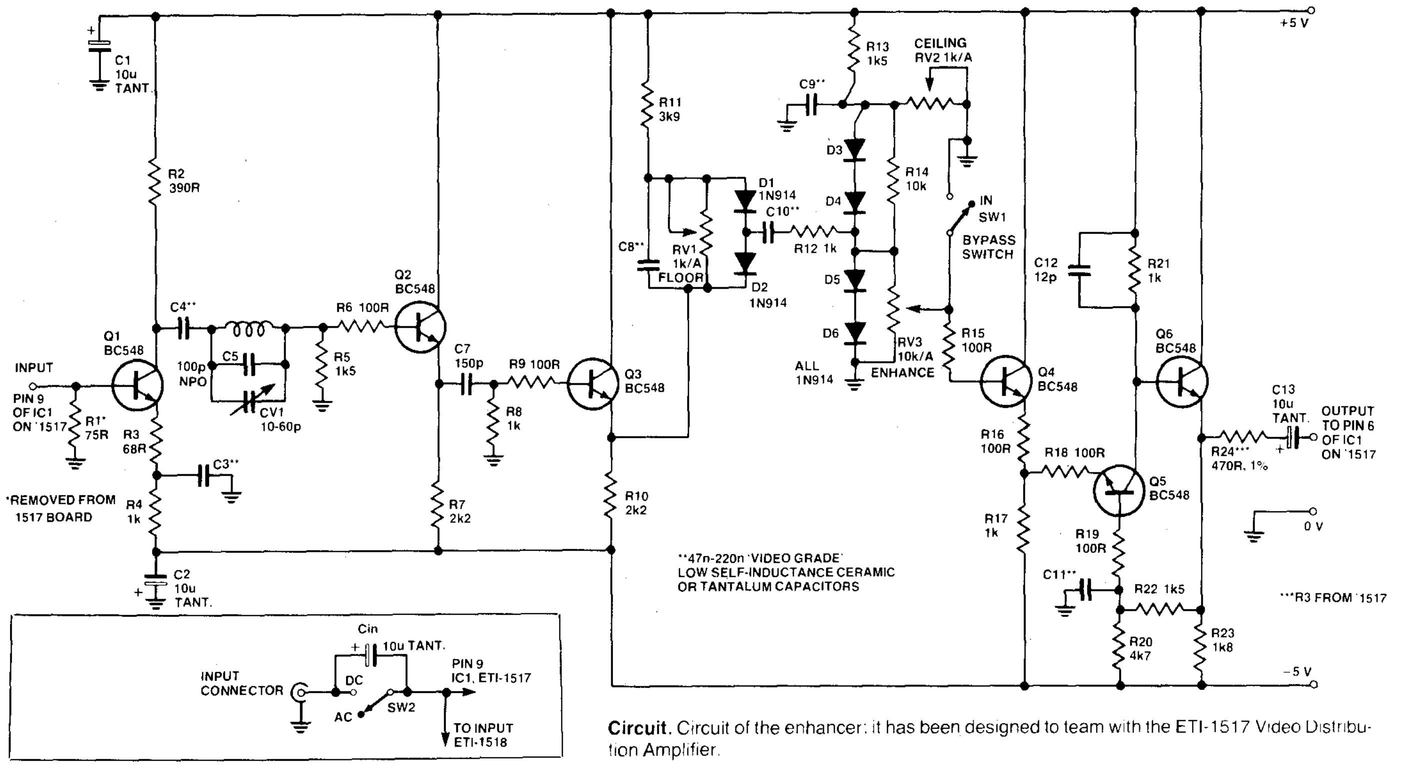
Many 'economy' video enhancers I've seen simply provide a single control, which sets the level of boost in the 2-5 MHz region. From experience, this is only effective on certain signals which have not suffered much degradation at all. Too many cases occur where you need to have some control of the signal level range over which the boost is applied. Thus, you see some commercial enhancers with a 'gamma' or 'core' control, which is there for just this purpose.

After some experimentation, I hit on a scheme that provided controls to adjust separately the minimum level from which boost is applied and the maximum level beyond which enhancement ceases. The minimum level I have dubbed *floor* and the maximum level control I have dubbed *ceiling*. Their function is obvious from the names. I prefer to work on the KISS theory ('Keep It Simple, Sam') and avoid jargon. Between the floor and ceiling, the amount of boost or enhancement can be varied from none to maximum with a control simply labelled *enhancement*. See? Simple, but 'deluxe'.

I notice that some VCRs have a direct-coupled output which sits at a mean dc level ▶



Controls. The enhancement control works between the limits set by the floor and ceiling controls.



*REMOVED FROM 1517 BOARD

**47n-220n 'VIDEO GRADE' LOW SELF-INDUCTANCE CERAMIC OR TANTALUM CAPACITORS

***R3 FROM '1517

Circuit. Circuit of the enhancer: it has been designed to team with the ETI-1517 Video Distribution Amplifier.

HOW IT WORKS — ETI-1518

I will assume you are familiar with the operation of the ETI-1517 Video Distribution Amplifier. You will recall that it consisted of a differential amplifier with the signal applied to the non-inverting input and equal value resistors placed from output to inverting input and inverting input to ground, giving a gain of exactly two from input to output before termination loss, and a gain of exactly one after.

The enhancer section of this project takes the input signal, removes the low frequency part of it, inverts it, processes it according to the control settings, then adds it (out of phase) to the original signal by applying it to the inverting input of the differential pair in the '1517. By maintaining the output impedance of the final processing stage at the value of the lower leg of the feedback divider in the '1517 (470R) the original signal path gain remains unchanged.

The effective addition of the processed high frequency content of the signal to the unaltered original is equivalent to boosting that high frequency information, which is enhancing.

Referring now to the circuit of the enhancer section, Q1 is a buffer stage with a gain of −4 approximately. Here the inversion necessary to reverse the eventual inversion of the differential pair is introduced. Q1 is biased in such a manner as to clip off sync pulse tops without saturating. This prevents them being fully enhanced, which is desirable.

It may be necessary to remove dc from the incoming signal to ensure that no video is clipped as well. For this reason, provision to ac couple the whole system is included. Most VCR inputs are expecting only ac coupling, and most outputs are not dc offset, so maintenance of dc levels is not as crucial as it sometimes is in circuits not equipped to 'dc restore' off the sync waveform.

Coil L1 and surrounding components form a 'trap' which excludes from the circuit the colour subcarrier. This should not be enhanced, so a notch is introduced at 4.43 MHz. The subcarrier thus passes only through the distribution amp and remains unaltered.

Transistor Q2 is a common collector buffer stage, giving a low output impedance for C7/R8, which form a low cut filter which is 3 dB down at 1 MHz. This selects only the high frequencies for further processing. Q3 is another buffer stage to prevent different processing steps interacting. The base decoupling resistors prevent possible buffer instabilites in the face of reactive loading.

Potentiometer RV1 and surrounding components form the floor or gamma processing stage. The aim of this stage is to make it possible to selectively pass higher amplitude signals. The motivation for this is that noise, particularly 'snowy' effects, is predominantly present in the high frequency part of the signal, but needs to be minimally enhanced. The noise is also predominantly lower in amplitude than brightness transitions in the video signal, which it is desirable to enhance. Hence it is possible to apply more enhancement to higher-amplitude components without enhancing noise. This function is sometimes referred to as 'core'. However, I think the label 'floor', for its obvious connection, or 'gamma' (less obvious) are more descriptive of its function.

Potentiometer RV2, plus D3-6 and associated components, provide the reverse function, which I labelled 'ceiling'. This section basically permits the setting of a level above which enhancement is reduced, by smoothly limiting the signal. I am not entirely convinced of the utility of the function, but include it for purists on the theory that winding the control clockwise removes it anyway. The idea behind this process is that the problem when enhancing certain signals is that ringing on full amplitude transitions induces nasty shadow lines: thus there is something to be gained by limiting enhancements of the high end of the amplitude range.

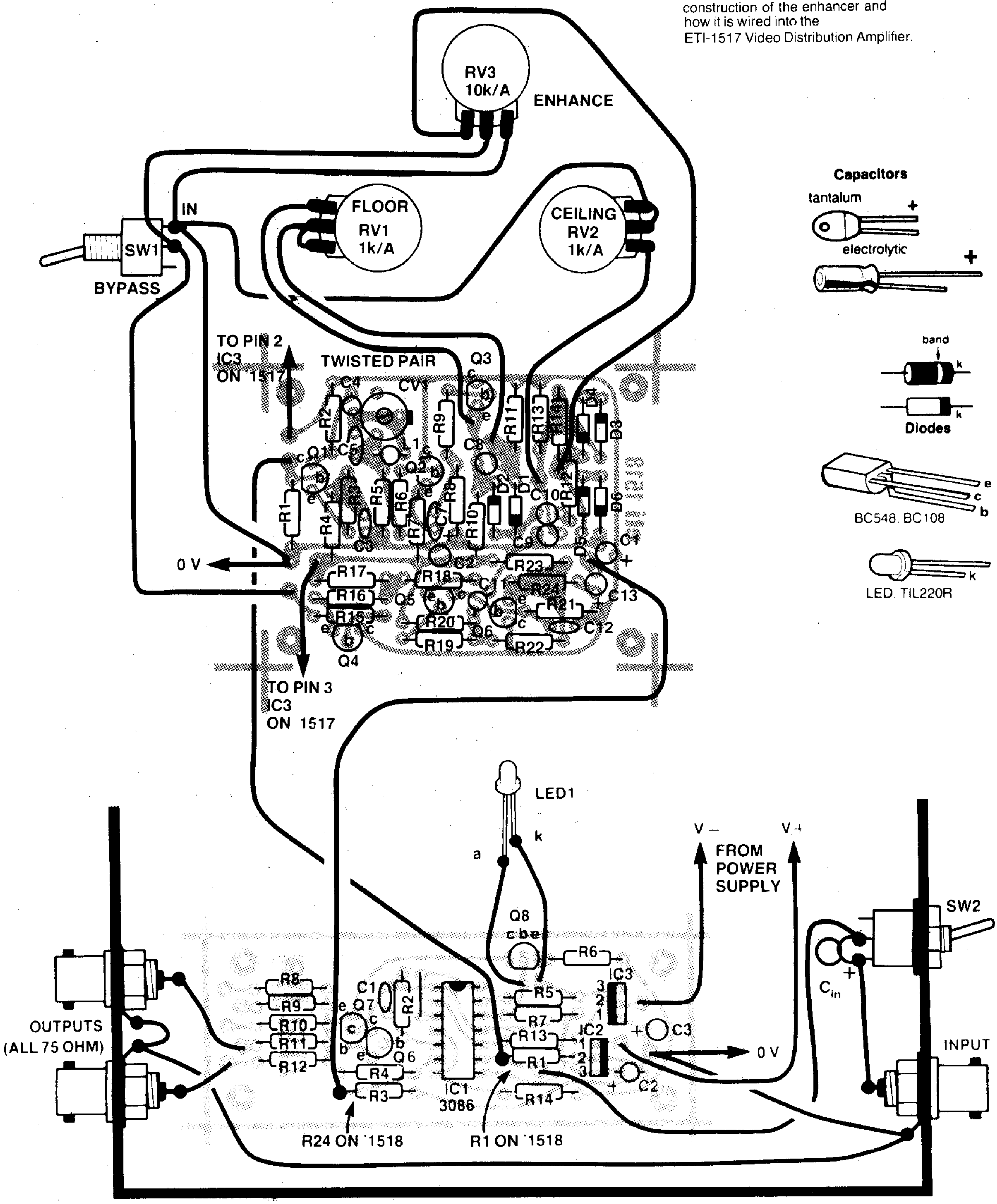
Both floor and ceiling circuits work in a similar way. Diodes, two in the former case and two pairs in the latter, are subjected to varying forward dc bias conditions.

To proceed further down the signal path (to the right on the circuit diagram), the video signal must get through the diodes in the floor case, and not get shorted out through the diodes in the ceiling case. If the difference between the dc bias present on the diodes and that necessary to make them conduct is larger than the instantaneous signal amplitude, the signal will not pass without attenuation. Of course, the effect is not that sharp, as the levels are chosen to make use of the diodes' turn-on characteristics to produce no gross discontinuities in the waveform.

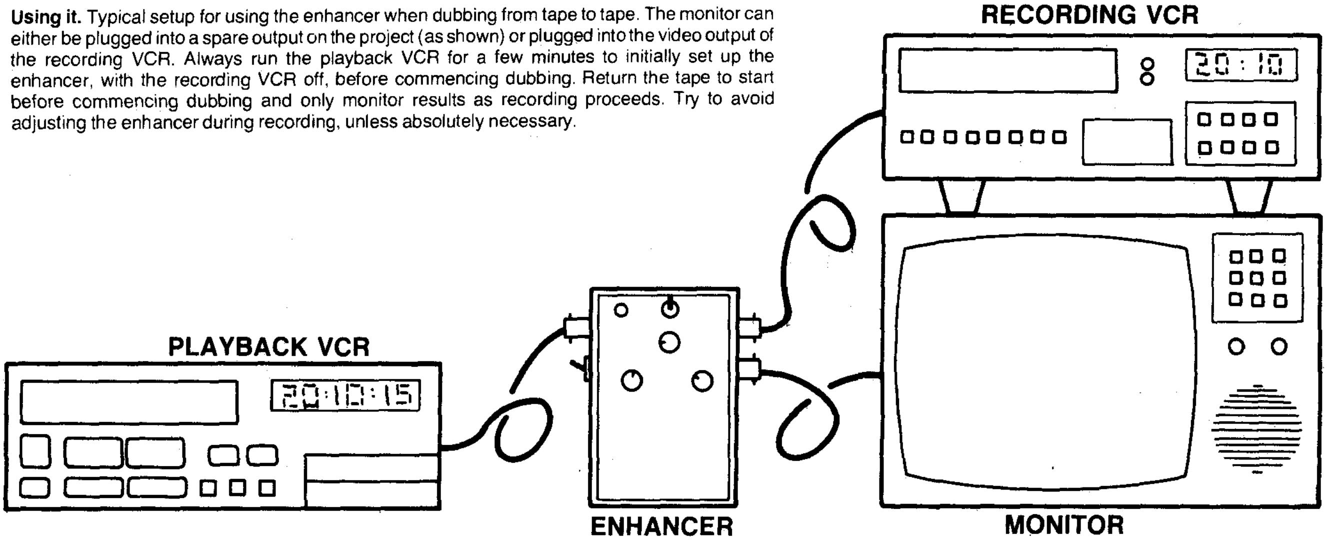
In the floor circuit, RV1 sets the bias on D1 and D2. Adjusted for maximum resistance, RV1 permits current to flow in the diodes turning them) on sufficiently to pass all the signal. At zero resistance only signals exceeding about half a volt pass, and then only their high-amplitude parts. These two extremes bound the useful region where mild selectivity of response is applied.

Signals not limited by the ceiling circuit are passed to RV3, which acts as a level control, setting the amount of signal passed back to the differential amplifier and hence the degree of enhancement. Transistors Q4-6 form a dc-coupled amplifier (in the form of a long-tailed pair and an emitter follower) which provides a gain of eight and a low output impedance. C13 and R24 pass the signal out and provide a precise 470 ohm impedance to ground for the feedback signal from distribution amplifiers.

The video amplifier output stage in the '1517 was designed to limit negative-going signals to an amplitude of about a volt. Thus, any gross overshoot on the partially limited sync pulses will be limited at that point. This occurs because the voltage gain is entirely vested in the differential pair, further stages providing only current gain. Q3 in the '1517's differential pair will saturate at a voltage corresponding to an output voltage of −2 V before matching loss.



Overlay and wiring diagram. Showing overall construction of the enhancer and how it is wired into the ETI-1517 Video Distribution Amplifier.



Using it. Typical setup for using the enhancer when dubbing from tape to tape. The monitor can either be plugged into a spare output on the project (as shown) or plugged into the video output of the recording VCR. Always run the playback VCR for a few minutes to initially set up the enhancer, with the recording VCR off, before commencing dubbing. Return the tape to start before commencing dubbing and only monitor results as recording proceeds. Try to avoid adjusting the enhancer during recording, unless absolutely necessary.

PARTS LIST — ETI-1518

Resistors	all ¼ W,5% unless noted
R1	75R, 1%*
R2	390R
R3	68R
R4,8,12,17,21	1k
R5,13,22	1k5
R6,9,15,16,18,19	100R
R7,10	2k2
R11	3k9
R14	10k
R20	4k7
R23	1k8
R24	470R,1%*
RV1,RV2	1k/A pots.
RV3	10k/A pot.

*may be taken from ETI-1517 board

Capacitors	
C1,2,13	10u/35 V tant.
C3,4,8,9,10,11	47n-220n ceramic (low inductance)
C5	100p ceramic NPO
C7	150p ceramic
C12	12p ceramic
CV1 (C6)	10-60p trimmer
Cin	10u/35 V tant.
Semiconductors	
D1-D6	1N914
Q1-Q6	BC548,BC549 etc.
Miscellaneous	
L1	10 uH RF choke (Q of at least 50)
SW1,SW2	SPST or SPDT min. toggle switches

ETI-1518 pc board; power supply +/−5 V (can come from ETI-1517); ETI-1517 (if you wish); Scotchcal front panel.

Price estimate
$18-$24 (alone)
$45-$50 (with ETI-1517)

of one to two volts or so. In a direct-coupled enhancer/distribution amp, this dc level can wreak havoc, clipping the video signal. Hence, I have provided the option of switching between ac and dc coupling. With ac coupling, some low frequency roll-off can be expected, but it's only slight.

Construction

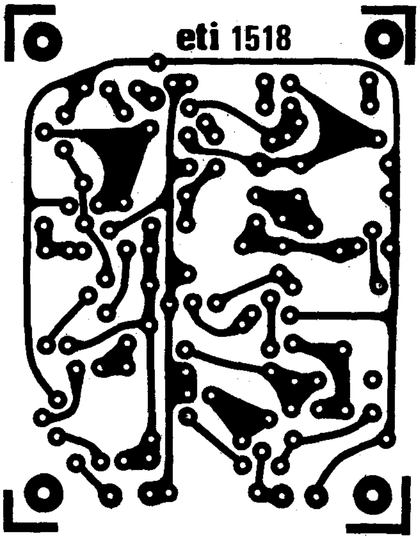
For the purposes of this discussion, I assume you have already built, or at least are prepared to build, the ETI-1517 Video Distribution Amplifier. The circuit presented here is designed to be used in conjunction with the previous circuit.

The first thing to do is locate a suitable position within the box for the new pc board and the new switches and potentiometers. There are three pots and one switch directly related to the enhancing section, and one additional switch to be added to permit ac coupling of the incoming signal.

The dc/ac coupling selection switch is ideally located near the input connector. The other controls may be laid out as you see fit or according to the front panel design reproduced here. If you're using a different layout, the controls should be as close as practical to each other and the location of the Video Enhancer board. The new enhancer is best located adjacent to the distribution amp board, but a few centimetres of spacing can be tolerated if required.

Once the layout is decided and the appropriate holes drilled in the case and panel, the board may be assembled according to the overlay diagram. As I anticipate that a number of our constructors will be basically video enthusiasts, not electronics enthusiasts, I will take the liberty of stressing how vital it is not only that each component be inserted the correct way around, but that each solder connection be clean and neat. Only the resistors and ceramic capacitors may be put in either way around without impairing the operation of the circuit. It is best to put in only half a dozen items at a time, starting with the resistors and capacitors, and then solder these into place, cutting the component leads after soldering. Resistors R2 and R24 should be left out for now.

Next, two modifications need to be made to the ETI-1517 board, or the whole must be constructed with these two variations taken into account. The first consists of removing the termination resistor from the input side of the ETI-1517 circuit. A termination resistor, nominally of 75 ohms and preferably a 2% type, is provided in the enhancer (R2), and hence the one in the distribution amp is unnecessary. It may be used as R2 in the enhancer circuit if you wish. A wire may then conveniently convey the input signal from the ETI-1517 to the ETI-1518, using the hole vacated by the resistor you have just removed or transferred.



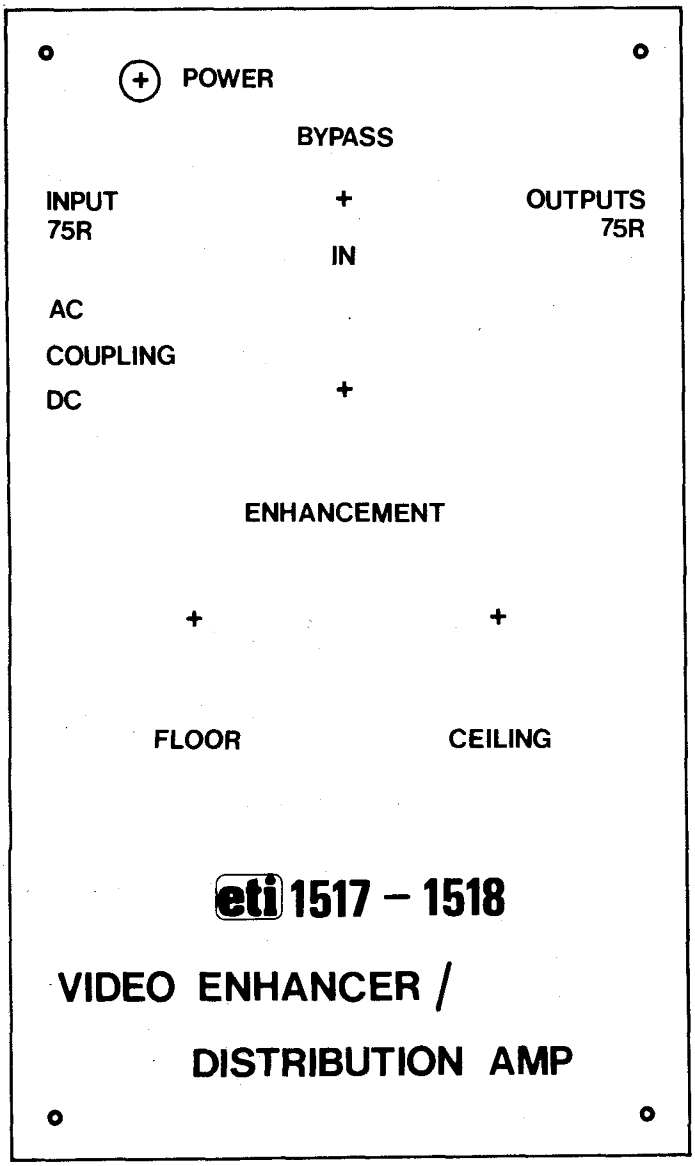
Board. Full-size pc board artwork

The second modification also consists of transferring a resistor. This time it is R24 in the enhancer circuit. Resistor R3 in the ETI-1517 (nominally 470R), running to ground from pin 6 of IC1, should be moved to R24 on the enhancer board. Recall that this resistor was a 1% or 2% type, or at least a selected value resistor. This is why it is transferred; the precise gain of the distribution amp is not disturbed. A wire is again run, using a vacated hole, this time from pin 6 of IC1 on the ETI-1517 to the output of the ETI-1518 enhancer board.

Now, apart from any beautification process you may wish to use, such as a Scotchcal panel fascia, the only remaining job is to hook up the flying leads to the ETI-1518 board. There are the leads to the pots and bypass switch, an earth and +/−5 volt leads, which may be run from underneath the ETI-1517 board, as well as the two signal leads already mentioned. My prototype layout is shown in the overlay/wiring diagram. Note that the various earth returns from connectors and boards, etc, all run to *one* convenient point. It is important to avoid any excessive lengths or tortuous paths in the signal and earth return leads, as this can easily provoke instability in a wide bandwidth circuit such as this.

At this point it seems appropriate to indicate that the compensation capacitor in the distribution circuit, the 27 pF capacitor in parallel with the collector resistor in the differential pair (C1), may require increasing to 33 or even 39 pF. Depending upon layouts and component tolerance, it appears that some units could exhibit unstable behaviour, especially on black-to-white transitions in the video signal. While my prototype was quite happy in a 'clean' environment, mismatches and other variations have subsequently been found to upset it. If super-video frequency ringing is evident on square-wave transitions with short risetimes, proper matching will cure it.

Finally, the video subcarrier trap must be adjusted. This entails adjusting the variable capacitor (CV1) to produce a 'notch' in the enhancer amplifier train at 4.43 MHz.



Front panel. Full-size reproduction of the front panel artwork.

Connect a generator, set to deliver a sinewave signal at 4.43 MHz of about 200 mV p-p into a 75 ohm load. Viewing the output with the bypass switch closed so as to pass unenhanced signal, verify that the output is the same as the input when terminated correctly. Switch in the enhancer part of the circuit, setting the floor low and the ceiling high (RV1 to maximum and RV2 to minimum resistance). Adjust RV3 to mid-position. Now adjust C6 for a minimum of output signal. This will be near, though not necessarily exactly at, the original output level before enhancement.

If you do not have access to the equipment needed to do this adjustment, you will not be able to set the enhancer trap correctly, but a setting satisfactory to your recorder should be obtainable simply by selecting that setting of CV1 which leaves the *colour* of the picture minimally disturbed throughout the travel of the enhancement control. If a range of settings fits this bill, leave the trimmer at the centre of the range.

Operation

Operation of the enhancer is quite straightforward, though some experience is necessary in optimising the control settings. The effects are subtle, but worthwhile if you do a lot of viewing and recording of video material.

Connect the enhancer between the video source you wish to enhance and the monitor or receiving VCR. If possible, choose some material with plenty of contrast and colour — commercials are good for this, if little else.

Initially, adjust the floor *down* and the ceiling *up*. Wind up the enhance knob. You will observe that the image first gets 'crisper', with fine print and signs, labels etc becoming more easily read. Eventually the snow and general noise gets significant, or perhaps the bright/dark transitions get shadowy, indicating too much boosting.

The noise problem can often be improved with judicious fiddling with the floor level. You will find that the floor and enhance functions are interactive to some extent. This is really a very fine point, because the amount of extra boost you can squeeze in with the use of the floor level control is usually minimal, but it is there.

Likewise, the transition overshoot problem, manifesting itself as rippled edges, can be improved with the ceiling function. This function may be rarely useful, but seeing the logic behind it, I included it for you to try out.

This control is also interactive, so the adjustment of all may be finnicky. I had better results by adjusting the enhance and floor controls until just too much enhancement was evident, then 'backing off' ceiling to just correct it.

A further check can be made by immediately playing back the copy. It is possible that over-enhancement to the immediate viewer can be just right when the signal has gone through another record-replay stage: sort of pre-enhancement.

About here is where the written advice is superseded by on-the-job fiddling with the knobs. I wish you all the best with your new project. ●

Video distribution amplifier

This simple, low-cost project will allow you to drive, say, five video monitors from one source, such as a video cassette recorder or a computer.

John Power

PIPING VIDEO around has become quite common place: from a computer to a video display unit, from a video cassette recorder to a video monitor, etc. Occasions arise, however, when you need to 'drive' more than one display or whatever, from a single source. For example; when playing a videotaped lecture at a club meeting, it's more convenient for the audience to have several monitors placed at appropriate positions rather than everyone trying to strain to watch one small screen. Or, when doing a computer/computing demonstration, it's much handier to have several monitors hooked up rather than have the audience crowd around the one. Anyway, I expect many readers will have their own applications already in mind for this project.

Design

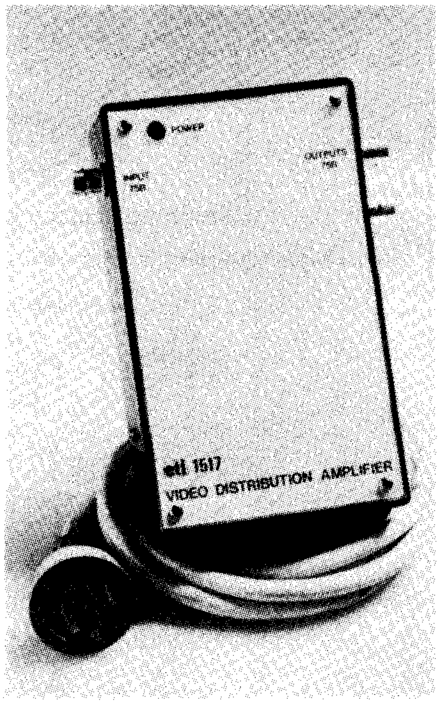
The requirements of a video distribution amplifier are quite straightforward. The unit must be able to take a single input and to drive the required number of outputs while retaining video fidelity. The bandwidth at full output level must be at least 5 MHz or more so as to retain video fidelity. The input and output impedances must be matched to standard 75 ohms widely used in video work and adding or subtracting units to or from the outputs should not affect any other device connected to an output. In essence, that's what this project does.

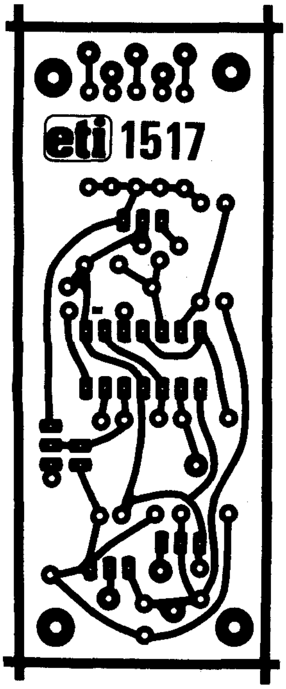
The heart of the unit is a transistor array IC — a CA3086. If you want to know more about this IC and its associated family, see Lab. Notes in the ETI November 1980 issue.

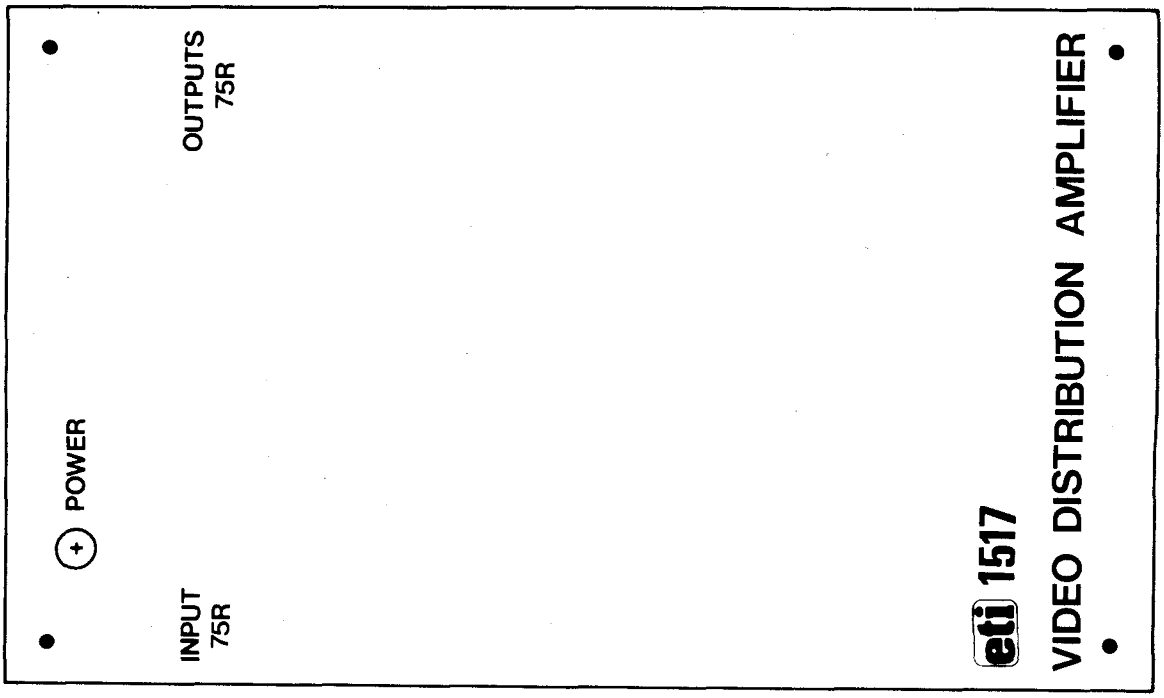
The transistors inside this package have been connected as a differential amplifier, the output of which drives a power output stage. Feedback provides a gain of one (i.e.: unity) and ensures a wide bandwidth. Regulated +/− 5 V supplies are used so that the whole amplifier can be direct-coupled, yet maintain the output point at dc earth potential. In practice, the 'dc offset' at the output is on the order of 100 mV or so (it could be positive or negative).

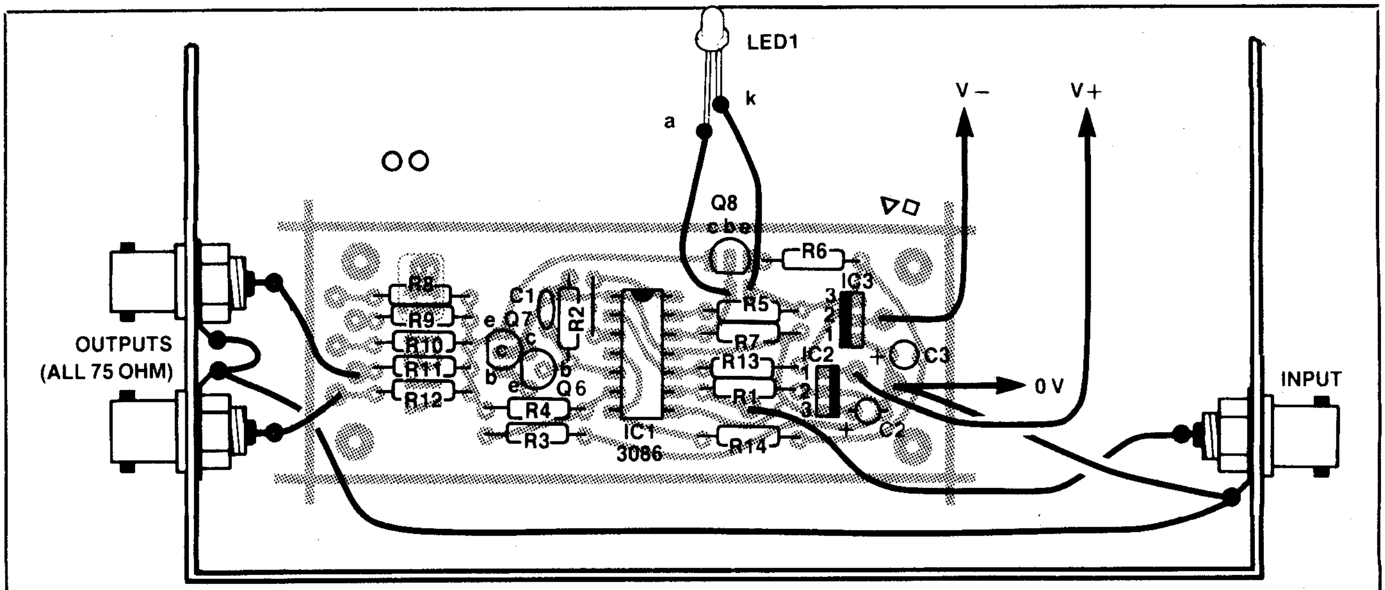
Construction

I built the video amplifier into a 50 x 95 x 158 mm jiffy box along with its own mains supply. This has the advantage of convenience, though it is possible to run the circuit off a 12 volt plugpack, which would make the whole a little cheaper if you already have the plugpack. Plugpacks are also safer for the constructor who is unfamiliar with mains wiring, though more

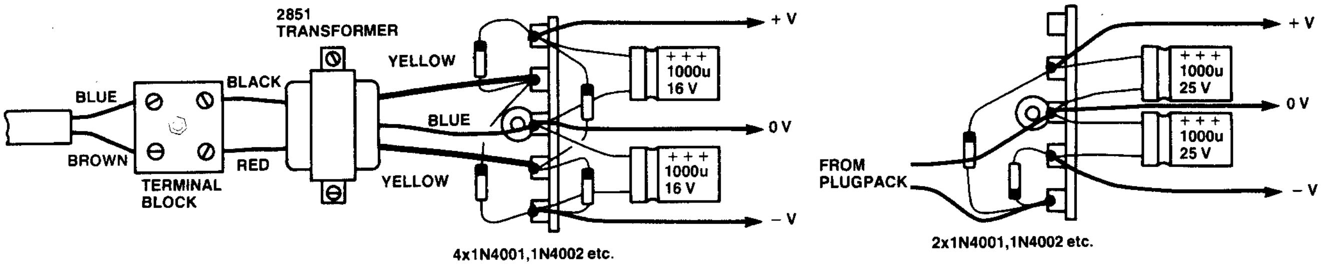








Overlay and wiring diagram. Showing how the pc board is assembled and wired up.



Power supplies. Wiring details for the two types of power supplies suggested.

expensive in the first place. Anyway, details are given for both situations.

In any case, the first stage is to select a box which will fit the parts comfortably. Ideally the project would be best in a tough metallic box, but the design is very stable and not liable to interference, so a cheaper plastic box such as the jiffy box I used is adequate, especially in a domestic situation.

Next, select the connectors you intend to use. Some video systems use RCA sockets and cables rather than the more robust BNC type. You may not require the full five outputs which the unit is capable of driving. Thus you may elect to economise and fit only two BNC sockets. (BNC sockets, if good ones, are not cheap). Or, you may fit two BNCs and an RCA type, in case. Note that solder lugs are needed for earthing.

Having selected the connectors you must decide on the power supply. I include the full mains transformer, rectifier, filter and so on, all of the components for which came to about half the cost of a plugpack, cord included! I recommend this approach as cost effective as well as convenient. (You cannot easily lose the parts you bolt in like you can lose a plugpack.)

Next, drill the box to allow the entry of the mains cable or the mounting of a plugpack connector as appropriate. Also, mounting holes for the connectors, the LED, printed circuit boards and power transformer, if applicable, will be needed.

It is convenient to use the pc board as a template for marking the position of its mounting holes, before you fit any components to the board. I placed the board right up one end of the box the power supply at the other end, leaving room for a video enhancer board in the middle.

It should be possible to use one of the transformer mounting bolts for a cable clamp to hold the mains cable if one of those special hole clamps is not used at the entry to the box. The ribbed insides of jiffy boxes often prevent the use of the hole clamp brackets and, as the cable must be clamped for safety reasons, be sure to allow for a clamp strap if you are not using a hole clamp.

Once the drilling is finished fit the components to the pc board after checking that all holes are correctly drilled and that all the tracks are OK. Be sure to get the ICs, and the tantalum capacitors and transistors the correct way around. If you are using a BD139 rather than BD639 for Q7, you will find that it has a different package and thus does not match the overlay diagram — be very careful to get it in the right way around. Attatch short lengths of hookup wire to the pc board input, output and power connections. These can be trimmed and soldered to their respective destinations once the board is bolted in place.

Next fit the transformer, mains cable and connectors in their respective positions in the box. Clamp the mains cable carefully and connect it to the terminal block, along with the transformer wires.

Now wire up the tagstrip, following the diagram carefully. Solder onto it the transformer secondary wires and the wires leading to the pc board. Mount the tagstrip and the pc board. Run an earth lead to each of the connector ground lugs, as shown in the wiring diagram, and then the 0V point on the pc board. Finally, connect the input and output leads and the LED wires.

Test

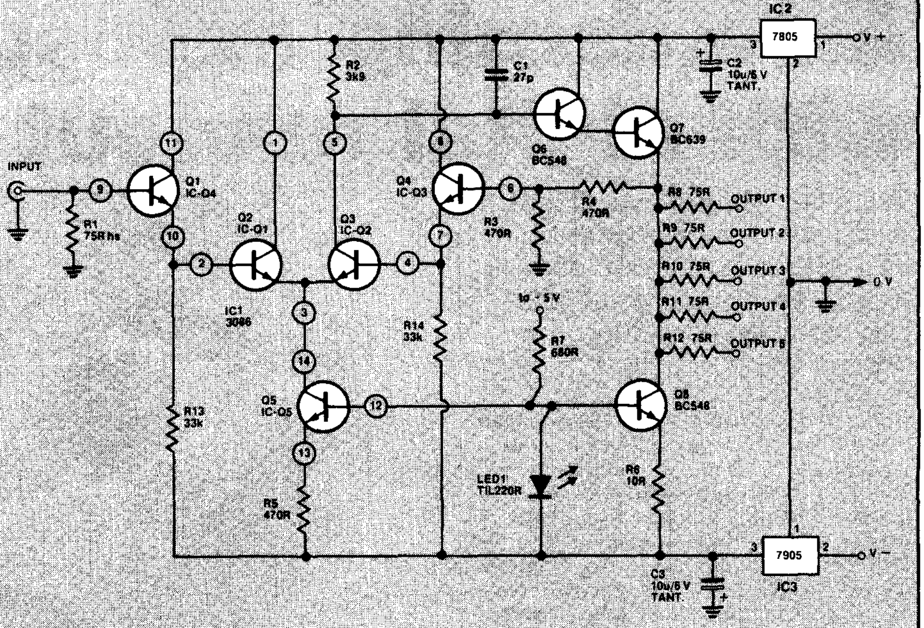
To test it, apply power and check that the rectifier outputs are correct. If you're using the 2851 transformer, you should measure around 9 V across each of the 1000u filter capacitors. If you're using the plugpack supply, you should get around 16-17 V across the 1000u filter capacitors. If they're OK, check the outputs of the two regulators. These should each be 5 V. The LED should be lit.

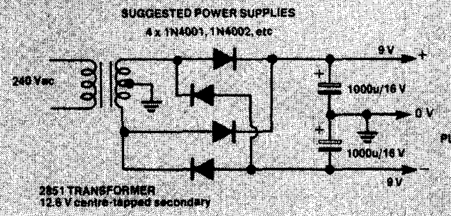
If there are any faults to this stage, switch off and sort them out before continuing. A wiring error is the usual culprit.

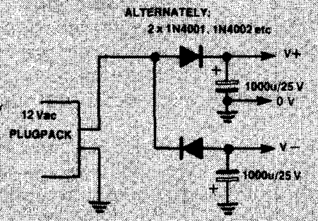
If all's well, connect it up and try it out.

●

HOW IT WORKS — ETI 1517







The unit is basically a dc-coupled feedback amplifier. It comprises a differential input stage, a buffer stage and a power output stage which together form a small but fast and powerful operational amplifier. This is suitably configured to give an overall gain into 75 ohm matched loads of precisely one, and a bandwidth of better than five megahertz — the requirement for a video distribution amplifier.

The differential input stage is created from a CA3086 IC (IC1) which contains five discrete transistors. Four (Q1 to Q4) are used to provide a Darlington long-tailed pair, with the fifth transistor (Q5) acting as the current source for the stage. The use of this IC, rather than having five discrete transistors guarantees good thermal matching for low offset and good matching of the transistors for predictable balance and gain.

The use of a Darlington configuration produces high input impedance and permits the stage to deliver an output swing sufficient to comfortably achieve the ±2 V required to deliver colour video levels into a matching resistor and load. The fifth transistor is set to deliver around 2 mA into the Darlington pair, using a red LED as a voltage reference; this LED doubles as the power-on indicator.

This current would provide a transconductance of sufficient value to give a gain of 35 if it were not for the two 33k resistors, R13-R14. These boost the gain to more like 65, as well as ensuring that charge storage effects in the bases of the two central transistors (Q2, Q3) do not limit the slew rate of the circuit to an unacceptable level.

The open loop bandwidth of the circuit is defined by the capacitor C1 in conjunction with the 3k9 load resistor, R2, and other minor effects.

Transistor Q6 is a common collector circuit which buffers the differential pair output and provides a negative dc shift of about 0.6 volts. Q7 and Q8 form the output stage. Q8 is a current source setting the output quiescent current to about 100 mA, which is required (worst case) to drive five parallel output lines of 75 Ohms each. Q7 is a common collector stage which drives the output. Q8 also uses the LED as a voltage reference.

A BC548 or similar transistor has been specified for Q8, though a slightly more powerful one is required for Q7. In fact Q8 is just below the rated power level for a BC548 while Q7 may just exceed the maximum current rating. Neither transistor is very critical, owing to the feedback-type design employed, so some substitution is possible.

Resistors R3 and R4 form the feedback ratio defining resistors. High stability metal film types have been specified here. In practice, they define the gain of the whole amplifier and hence should be precise enough to ensure that the standard video levels are maintained. However, their value is not critical, only that they should be equal. It would be possible to use a pair of selected resistors of any value from 330 to 560 Ohms.

The input termination resistor and the output termination resistors are also specified as metal film types. This is in order to minimise mismatches with the cables used to connect to other video systems. It would be possible to use 47 or 51 Ohm metal film resistors if your system is 50 Ohm. In this case, the output stage could handle only four parallel loads.

The amplifier runs off + and −5 volts, provided by two three-terminal regulators. These are prevented from oscillating by the two tantalum capacitors, C2 and C3, which also provide supply rail bypassing over a wide bandwidth.

SPECIFICATIONS ETI-1517 VIDEO DISTRIBUTION AMPLIFIER

Number of outputs	up to five
Peak output	2 V peak-to-peak
Power bandwidth	8 MHz (-3 dB @ 1 Vp-p output)
Small signal bandwidth	26 MHz (- 3 dB @ 200 mVp-p output)
Input impedance	75 ohms
Output impedance	75 ohms (any port)

(performance measured on prototype)

PARTS LIST ETI-1517

Resistors	all ¼W, 5% unless noted
R1, R8-12	75R, 1%
R2	3k9
R3, R4	470R, 1%
R5	470R
R6	10R
R7	680R
R13, R14	33k
Capacitors	
C1	27p
C2, C3	10u/6 V tant.
Semiconductors	
IC1	CA3086, LM3086
IC2	uA7805, LM7805, LM340/T5
IC3	uA7905, LM7905, LM345/T5.0
Q6, Q8	BC548
Q7	BC639
LED1	TIL220R red LED

Miscellaneous

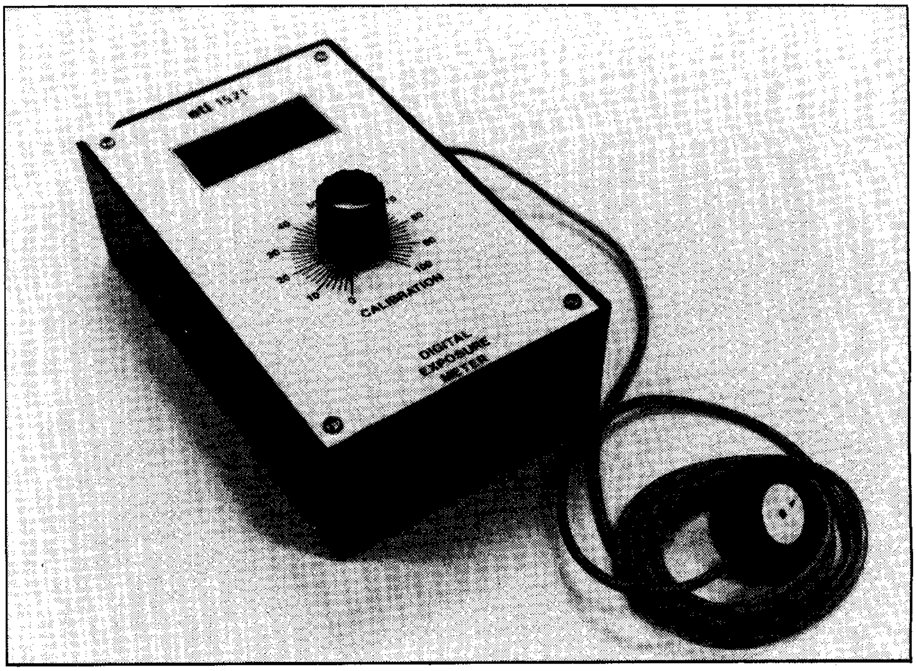
ETI-1517 pc board; UB1 zippy box (50x90x150 mm); required number of BNC sockets; Scotchcal front panel; plugpack (12 Vac) or power supply components to suit — see text; wire, nuts, bolts, etc.

Price estimate: $35-$45

An enlarging exposure meter with digital readout

Peter Ihnat

With this project you'll get a higher yield of decent exposures from your darkroom. It includes a sensor that compensates for 'cosine error'.



NUMEROUS photographers develop their own films and prints in anything from well-equipped darkrooms to bathrooms and laundries made light-tight with blanket-covered windows. Rapidly rising costs of 'commercial' production, coupled with the fact that the photographer has complete control over the finished product, are some of the reasons for photographers "rolling their own". Fortunately, there is a surprisingly small number of electronic gadgets necessary in the darkroom to produce good quality black and white and colour prints. Even so, darkroom oriented projects in electronic magazines are few and far between.

One electronic gadget which is a must in the darkroom is an exposure meter — a device which quickly and accurately indicates exposure time and ends up paying for itself in terms of time and photographic paper saved. The current project evolved when I decided to buy a commercial exposure meter and soon realised a digital one could be built for the same cost as a simple commercial "two-LED comparative" type.

The device described here is very simple to operate since it consists of a remote probe (light detector), three-digit display (which indicates exposure time in seconds) and a "calibration" control on the front panel. One simply puts the sensor on the brightest area of the enlarger baseboard and the meter will indicate the correct exposure time. But more of this later. Let's look at the design details and construction.

Circuit description

The basic idea behind the unit's operation is to produce a digital output inversely proportional to the intensity of light falling on a sensor. Why inversely proportional, you might ask? Well, for a given type of photographic paper, the light intensity times the required exposure time is a constant (which takes into account the speed of the paper and the spectral "colour" of the enlarging lamp). Mathematically:

$$I \times E = C \qquad [i]$$

where I = light intensity, E = exposure time and C = a constant.

Since we need the output from the meter to be E, the equation can be rearranged as follows:

$$E = C/I \qquad [ii]$$

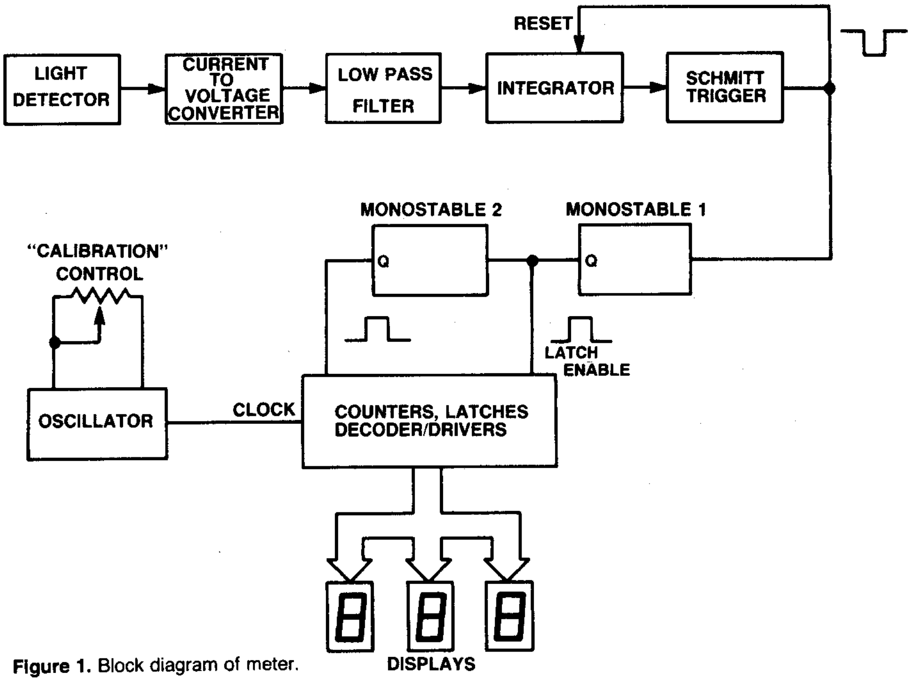
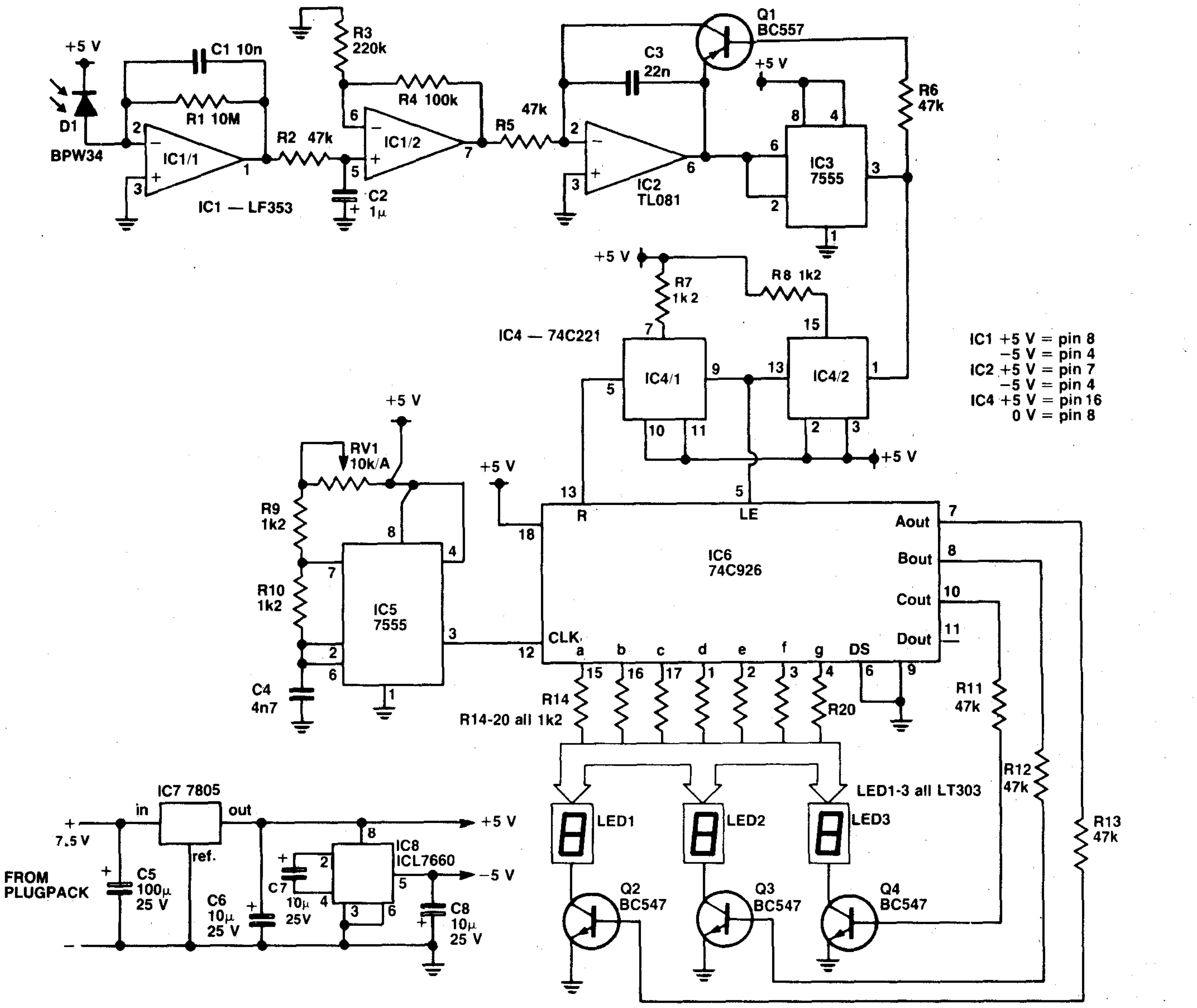


Figure 1. Block diagram of meter.

Notice that the exposure is *inversely* proportional to light intensity — the more light you have the less exposure is necessary. How is C handled by this meter? It's the "calibration" control on the front panel!

Figure 1 shows the block diagram of the meter. Originally, I used a phototransistor as the light sensor and it worked well at high light levels. Unfortunately, at the low light levels typically encountered in darkrooms (0.001 — 10 foot candelas) the response was highly non-linear. The alternative was to use a photodiode as a light-to-current converter — the current then being ▶



HOW IT WORKS

The meter simply provides gating pulses whose period is inversely proportional to the intensity of the incident light. The pulses gate counts for a master oscillator into a four-digit counter which then displays the reading obtained.

Light falling on photodiode D1 produces a proportional current which is converted to a negative voltage by op-amp IC1/1. Resistor R1 affects the sensitivity and C1 is used to filter out any stray ac signals (HF and LF) picked up by the remote probe and connecting cable. IC1/2 is set up as a low pass filter with a gain of approximately 1.5 (= R4/(R3 + 1) and a cutoff frequency of approximately 3 Hz (= 1/(2.R2C2)). A first order filter is sufficient here since at 100 Hz the gain is approximately five octaves by −6 dB/octave = −30 dB.

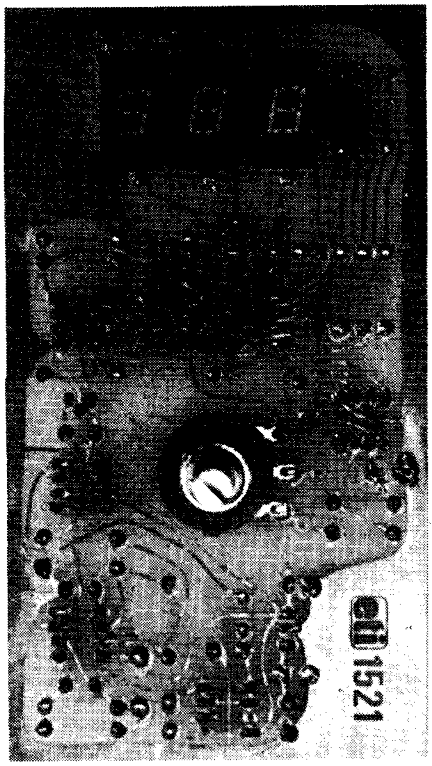
IC2 and IC3 together form a voltage-to-frequency converter. IC3 is a 7555 timer set up as a Schmitt trigger with trigger levels set at 1/3 and 2/3 of the supply, i.e: 1.6 V and 3.3 V. IC2 is connected as an integrator and Q1 is used as a resetting switch. Operation is as follows — assume Q1 is initially off. A constant negative voltage applied to the input of the integrator causes the output voltage to increase linearly while charging C3.

When the output voltage exceeds the upper trigger level of the Schmitt (3.3 V), it's output goes LOW which switches on Q1, discharging the integrator capacitor. The output of the integrator falls until it equals the Schmitt's lower trigger level (1.6 V). This sets the Schmitt's output HIGH again switching off Q1, allowing the cycle to repeat. The length of the cycle is inversely proportional to the magnitude of the voltage applied to the integrator.

The integrator reset pulse (from the Schmitt trigger) is used to trigger monostable IC4/2 which in turn triggers monostable IC4/1. The two respective outputs put active-high pulses on the latch enable (LE) and reset (R) inputs of the counter IC6 (refer to Figure 3 for relevant timing information) to latch the current count and reset the counter. IC6 is basically a four-digit counter with latches, decoders and multiplexer (to drive four displays) all in the one package. This has the advantage of low component count and low power dissipation.

Note that resistors R14-R20 control the brightness of the displays and can be varied to suit. The least significant digit of the counter seems not to be used but is actually used as a divide-by-ten stage to reduce jitter in the final display. IC5 is the master oscillator whose frequency is controlled by RV1. It is a typical astable oscillator based on the 7555 timer.

Power for the meter is derived from a 7.5 V plugpack. The positive supply (+5 V) is produced by a 7805 voltage regulator. Since a split supply is required for the op-amps. I used the Intersil ICL7660 CMOS voltage converter to produce −5 V directly from the +5 V supply. This IC, plus two other components (C7 and C8), produce a very simple and effective negative supply generator. Refer to ETI July 1982, page 51 for a technical description of the IC.



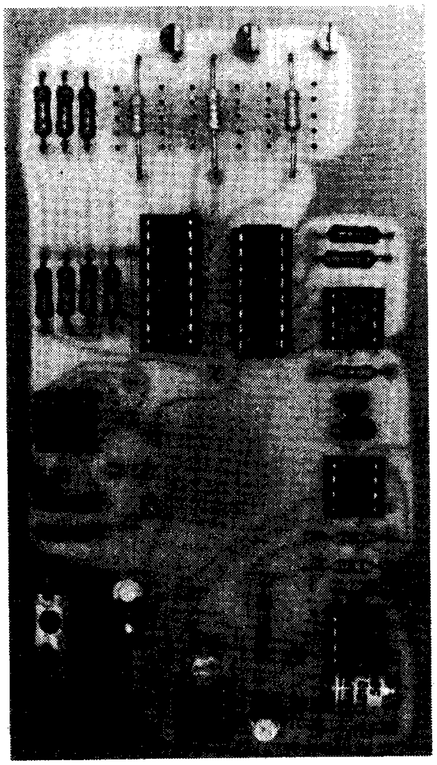


Figure 2(a). Photovoltaic mode.

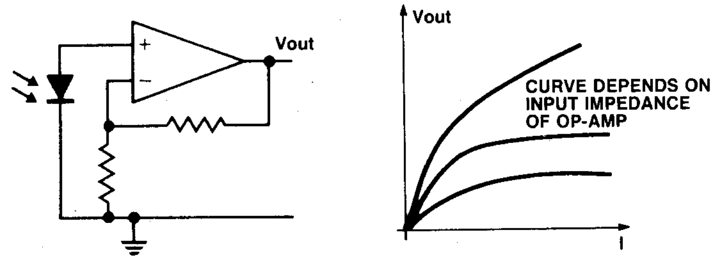
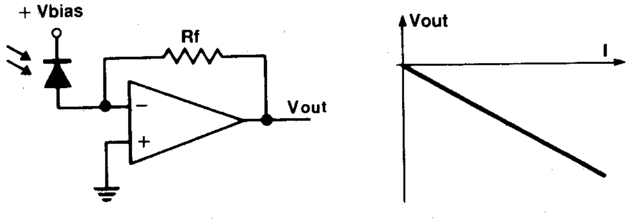
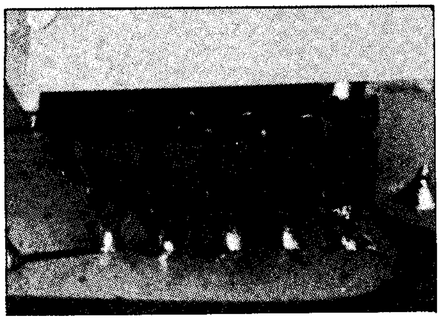


Figure 2(b). Photocurrent method.





The trickiest part of the construction is the mounting of the molex pins which hold the 7-segment display on the copper side of the pc board.

converted into a voltage by an appropriate op-amp circuit. Figure 2 shows two possible methods.

The photovoltaic mode shown in Figure 2(a) unfortunately has a logarithmic transfer characteristic so I used the photocurrent method (Figure 2(b)) which has a very linear response. The diode I used is the BPW34 which is commonly available. Unfortunately, photodiodes which cover the same spectral range as the eye are difficult to obtain in Australia. The BPW34 has its peak response at 850 nanometres wavelength which is well in the red but since all enlargers use incandescent lamps of some description, no problems arise.

PARTS LIST — ETI-1521

Resistors	all ¼W, 5%
R1	10M, 10%
R2, 5, 6, 11, 12, 13	47k
R3	220k
R4	100k
R7, 8, 9, 10, 14-20	1k2
RV1	10k/A see text
Capacitors	
C1	10n poly
C2	1µ/10 V tant.
C3	22n greencap
C4	4n7 greencap
C5	100µ/25 V electro. radial leads
C6, 7, 8	10µ/25 V electro. radial leads
Semiconductors	
D1	BPW34
IC1	TL082, TL072, LF353 or sim.
IC2	TL081, TL071 or sim.
IC3, IC5	7555
IC4	74C221
IC6	74C926
IC7	7805, LM340T/5
IC8	ICL7660
Q1	BC557, BC558, BC559 or sim.
Q2, 3, 4	BC547, BC548, BC549 or sim.
LED1, 2, 3	LT303, HP5082-7740 or sim. common-cathode 7-seg. displays
Miscellaneous	
SW1	DPDT slide switch (optional)

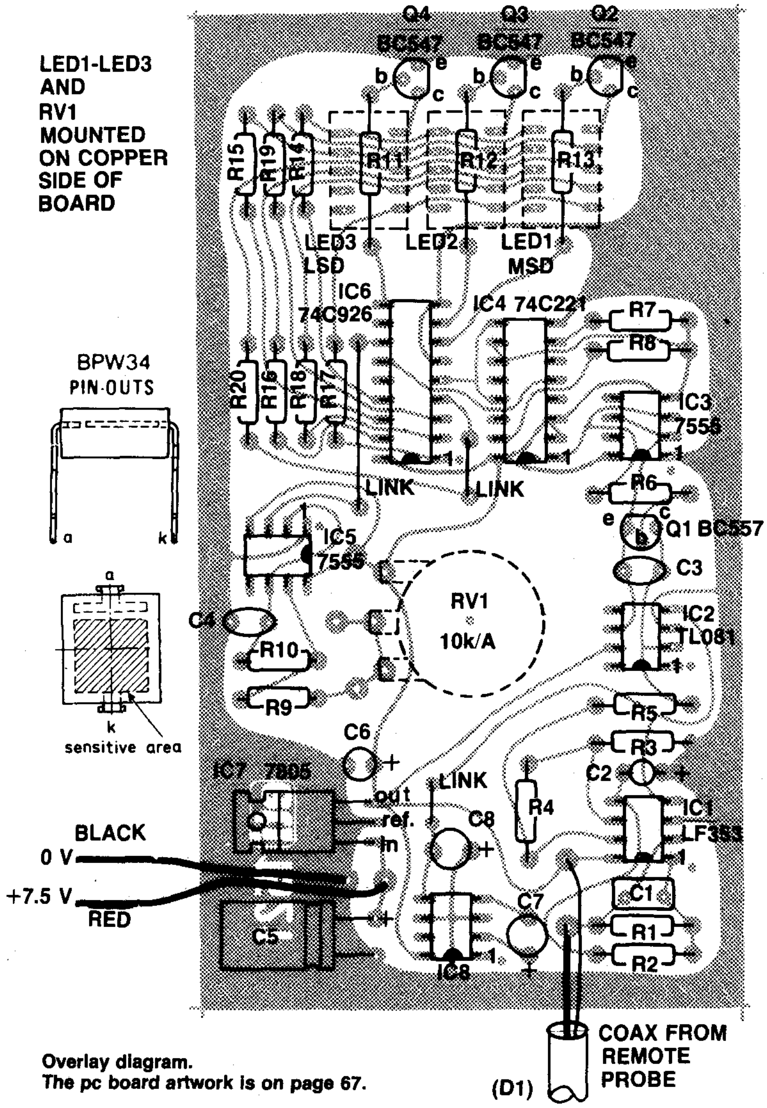
ETI-1521 pc board; dc plugpack with 7.5 V output (e.g: DSE cat. no. M-9526 or similar); coaxial socket to suit plugpack connector; zippy box 158 x 95 x 50 mm; half metre length of single core shielded cable; 35 mm film container; strip of 50 Molex pins; 30 x 60 mm piece of red filter; 5 x 8-pin IC sockets; 1 x 16-pin IC socket; 1 x 18-pin IC socket; hookup wire; Scotchal front panel label; nuts & bolts, etc.

Price estimate: $65-$73

The output voltage from the first stage is proportional to the intensity of the incident light but unless you have an enlarger which operates from a dc power supply, this voltage will have a significant 100 Hz ac component. The signal is then passed through a low pass filter to remove the ac and finally feeds the input of an integrator — a voltage-to-frequency converter. But since we need a signal which is inversely proportional to the light intensity, I have used the period of the waveform produced to gate the output of a master oscillator into the digital counter. The master oscillator essentially runs at some constant frequency which is set by the "calibration" control. The overall timing diagram shown in Figure 3.

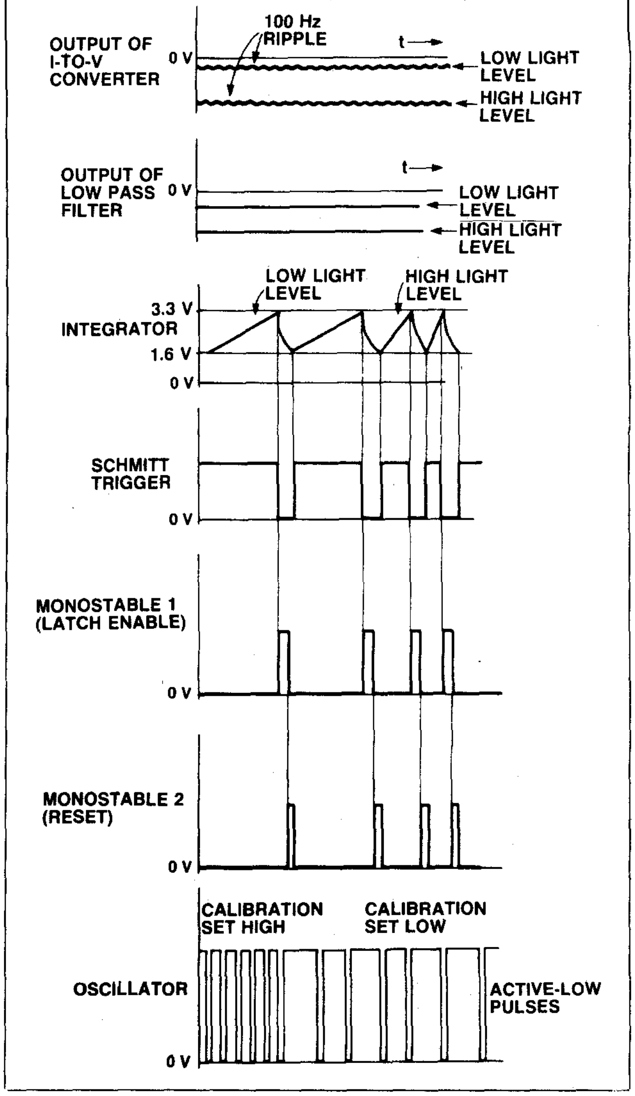
Construction

If the project is assembled on the pc board I designed for it, then there should be little trouble with construction. A close visual inspection of the pc board should be done before assembly to see there are no cracks in tracks or bridges between tracks or pads. See that all the holes are correctly drilled. Firstly, insert and solder the three wire



Overlay diagram.
The pc board artwork is on page 67.

Figure 3. Overall timing diagram.



links, then the resistors (except R11-R13) and capacitors. It is recommended that IC sockets be used and these should be soldered in next followed by the 7805 voltage regulator, IC7.

The trickiest part of the construction is the mounting of the molex pins which hold the 7-segment displays. Note that these and the calibration potentiometer are mounted on the *copper side* of the pc board. The tracks around the 7-segment display area are very close together and so great care must be taken to avoid solder bridges between tracks or even worse, overheating the tracks causing them to lift. The following procedure should only be attempted with a fine-to-medium tipped iron.

Firstly, break the molex strip into six strips of five pins each. Using emery paper or steel wool, clean the oxide coating off the part which will be soldered. I noticed while constructing the prototype that any rubbish on these pins caused a weak solder joint to be produced and several pins came loose when I attempted to insert the displays. These loose pins are extremely hard to replace without producing solder bridges and so the extra time spent cleaning saves problems later on.

When cleaned, a strip of five pins can then be inserted until the ends just show through the reverse (component) side of the board. The pins should be soldered before continuing with the other strips (if all six are inserted first, it will be almost impossible to solder them). The connecting bridges can then be carefully removed.

The remaining resistors and the transistors can now be mounted along with RV1. As mentioned before, RV1 is mounted on the copper side of the board and since the completed pc board "hangs off it", a drop of Araldite can be used to hold the two together with greater reliability.

Talking about reliability, a normal carbon pot can be used for RV1 but since these get dusty and end up with "dead" spots, I recommend a cermet, or conductive plastic type, such as the ones made by Bourns. If these are hard to get hold of I have made provision on the board for mounting the standard type. At this stage, the board can be powered up and the supply voltages checked. If all is OK, the ICs and displays can be inserted ensuring that they are all orientated correctly. To aid insertion, the pins on the 7-segment displays should first be straightened with long nose pliers.

Now on to the mechanics. The prototype was mounted in a 158 x 95 x 50 mm zippy box. The pc board itself is mounted on the lid of the box by means of RV1. I used two nuts on the pot shaft — one below and the other above the lid to position the board at a suitable distance from the lid. The artwork for the Scotchal front panel is reproduced elsewhere in this article. I mounted the on/off switch (optional) and power socket (to suit a plug pack) on the left side of the unit.

Remote probe

The BPW34 photo diode can be mounted in any convenient container to act as a remote probe, e.g: a pill box lid. Note that this container should not be very high since you need to measure the light intensity as close as possible to the base board of your enlarger where the photographic paper will sit. A 50 mm high container may not make much difference to your reading when mak- ▶

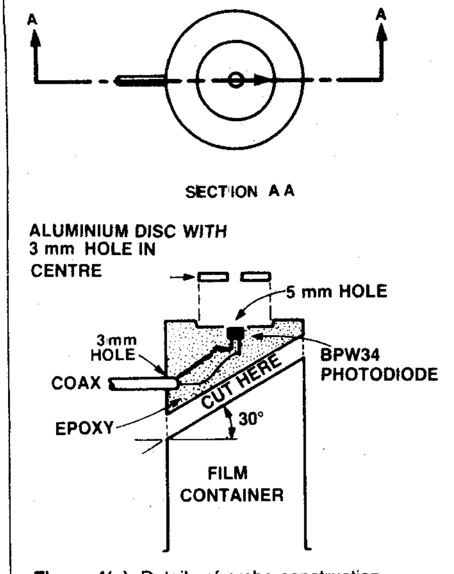


Figure 4(a). Details of probe construction.

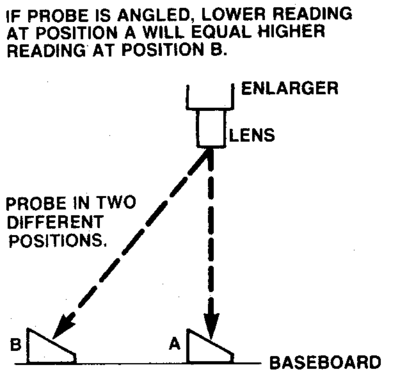

IF PROBE IS ANGLED, LOWER READING AT POSITION A WILL EQUAL HIGHER READING AT POSITION B.
ENLARGER
LENS
PROBE IN TWO DIFFERENT POSITIONS.
B
A
BASEBOARD

Figure 4(b). 'Cosine error' correction.

ing big enlargements, but for small prints when the lens may be only 100 mm from the baseboard, there will be a significant error.

For the prototype I cut the end off an unused film container (you know — the black plastic container that 35 mm film comes in) and drilled two holes in it — a 5 mm one in the top to hold the photo diode and a 3 mm one in the side to pass the coax through (see Figure 4(a)). On top I glued a 17 mm diameter aluminium disc with a 3 mm hole drilled in it to let light through to the diode. I painted the disc white to help when positioning under the enlarger. Filling the probe with epoxy completes it's construction and results in a very durable and compact unit.

Note also that the probe is tilted at an angle of 30° to the horizontal. This is to provide some "cosine error" correction. Cosine error is most easily observed when the enlarger is switched on without any film in the carrier. If a light reading is taken directly beneath the lens and another near the edge of the baseboard, there will be a significant difference between the two. In actual fact, the two readings should be identical since the idea of an enlarger is to provide even illumination over the entire area of a negative. The error exists since the light reaching the sensor when at the edge of the baseboard hits it at an angle, whereas directly below the lens the light rays are perpendicular to it. Any sensor experiences a drop in sensitivity as the angle of the incident radiation increases (with respect to the vertical). One easy way of correcting for this is to angle the sensor permanently. Then, when readings are taken beneath the lens, the angled sensor has slightly reduced sensitivity and will give a reading equal to that taken near the edges where the light falls directly onto it (see Figure 4(b)). For consistency, I placed an arrow on the probe and orientate it to point towards the centre of the baseboard when taking all readings.

Operation

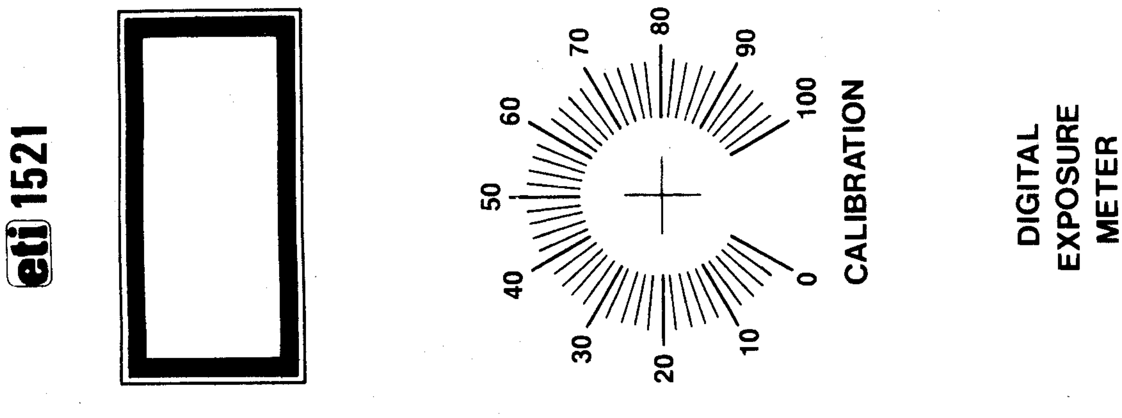
The unit itself is very easy to use and needs only one control, the "calibration" control, to be set for each type of paper you use, e.g: Ilfospeed, Bromide, Ektaprint 2 etc. The idea is initially to prepare a test strip of your "standard" negative or slide to determine the correct exposure.

Let's assume for Ilfospeed grade 3 paper you find that 12 seconds is the correct exposure for your negative. Without changing the lens f-stop or enlarger height, position the probe on the *brightest* area of the baseboard and adjust the calibration control until the meter reads 12. The exposure meter is now calibrated for this type of paper and the reading from the dial should be written on the outside of its packet. The next time you produce prints on this paper you simply set the meter to the setting previously determined, position the probe on the brightest area of the projected image and adjust the lens aperture until the meter gives a reasonable reading, say between five and 60 seconds. Then expose for the indicated time.

Note that a test strip is only necessary when *initially* setting up the unit and not each time it is used. Also, since the meter is used to measure the intensity of the brightest area of the negative, this corresponds to allowing sufficient light through the lightest area of the negative to *just* produce black on the paper in this area. The other shades of darkening will then fall in line to produce a correctly exposed print.

Happy exposing!! ●

Front panel artwork.



The printed circuit board pattern is on page 130.

These compact three-way speakers are easy to build and provide a wide-range response

Roger Harrison

Since we published a number of economical hi-fi amplifiers over the past few years, we have had increasing requests for speakers to suit. With the cooperation of Dick Smith Electronics, here is a three-way design that is compact and gives good performance at an economical price.

NOT EVERYONE likes the loudspeakers of a stereo hi-fi system to dominate the loungeroom furniture. Indeed, 'bookshelf' and 'compact' loudspeakers have long been popular, particularly amongst those who live in units or townhouses. While these speakers are certainly compact, they aren't quite as small as many bookshelf models on the market. They stand two-thirds of a metre tall and measure a little over 300 mm wide by 230 mm deep overall.

Tiny bookshelf loudspeakers may have a significant drawback. It is extremely difficult to achieve reasonable bass response in a small cabinet. Since much popular music, and certainly much classical music, has a great deal of bass content, a bass response extending below 100 Hz is important.

Design aspects

This loudspeaker employs a 'pressure box' or 'infinite baffle' design. That is, the box is completely sealed. It is sometimes called an 'acoustic suspension' system, too. Such an enclosure prevents sound radiated from the front of the drivers being coupled to the sound radiated from the rear of the drivers and causing constructive and destructive interference which produces big peaks and dips in the frequency response.

Why use three drivers? Well, a loudspeaker of the type used here — that is, the moving coil type — will only operate over a limited frequency range where the cone acts as a 'piston'. Below a certain frequency, the area of the cone will not move enough air to create audible sound waves. At the other end of the range, the sound commences to travel out *along* the cone, which no longer acts as a piston and the sound output drops off because compression and rarefraction waves are generated which tend to cancel each other.

Ideally, in designing a loudspeaker, any driver should be used only over its 'piston operating range'. The problem is, all but the most expensive and/or specially constructed drivers only have a piston operating range of three to four octaves (an octave is a 2:1 frequency range). You can use a driver over a greater range if some compromises are accepted — otherwise you'd end up with a speaker having five drivers to cover the 10 octaves of the audio spectrum! Expensive.

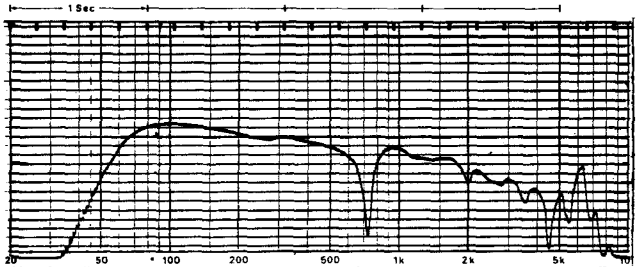
A popular technique is to use three drivers (hence 'three-way'); one to cover the bass end (the 'woofer') below 1 kHz, one to cover the mid-range from 1 kHz to 4 kHz or 5 kHz and one (usually called the 'tweeter') to cover the top end above that. Acknowledging that the most sensitive portion of the ear's frequency response is in the mid-range, three-way designs generally concentrate on using the mid-range driver over its piston operating range and accepting compromise operation with the other two drivers. That's what has been done with this project — and it achieves quite an acceptable result.

The bass response in a pressure box design is very dependent on the internal volume of the box. The bass driver, the air contained within the box, and the box's volume and shape all interact in a very complex way and it's a bit of a juggling act to make the best of things.

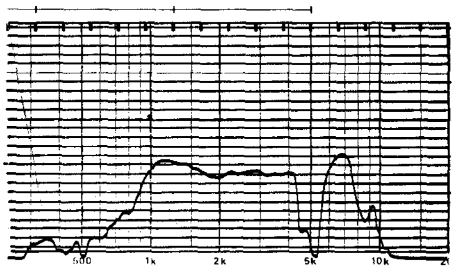
Basically, a sealed box with a driver in it acts like a high-pass filter. That is, the frequency response drops off rapidly below a certain frequency — the 'rolloff' or the 'corner' frequency. The greater the internal volume of the box, the lower the corner

NOMINAL SPECIFICATIONS ETI-421 3-WAY SPEAKERS

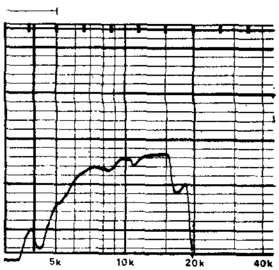
Nominal impedance	8 ohms
Frequency response	45 Hz to 17 kHz (−6 dB) 45 Hz to 19 kHz (−10 dB)
Nominal power handling	40 watts
Box volume	30 litres



Woofer. The piston operating range extends over at least three octaves. The 'dip' near 700 Hz does not show up in the overall response. Vertical scale: 1 dB/increment.



Mid-range. Its piston operating range extends from about 1 kHz to about 4.5 kHz.



Tweeter. This shows reasonable response from about 5-15 kHz.

frequency — and vice versa. But there's a limit to the size of the speaker enclosure that "... s/he who must be obeyed" will accept in the loungeroom. Another compromise — but *this one*'s easy to satisfy and still get good bass response.

The enclosure dimensions settled on for this project result in quite a compact box having an internal volume of near as damn to 30 litres which, together with the 200 mm bass driver selected, delivers a bass end which extends to 60 Hz. Not a bad result. Many compact and bookshelf speakers barely make it to 100 Hz.

The mid-range and tweeter both have a sealed rear so that sound pressure inside the box, from the bass driver, does not interfere with their operation.

The piston operating range of the mid-range driver chosen appears to extend from about 1 kHz to 4.5 kHz or thereabouts. Hence, this determines where the operation of the other two drivers has to 'cross-over', from bass to mid-range and mid-range to tweeter. A filter system is used to effect this, rather than just connecting all the drivers in parallel. This filter is called the 'crossover network'.

The response of the bass driver is 'rolled off' at the frequency where you want it to cross-over into the mid-range. Thus, a low pass filter is employed. In this case, a simple inductor (L2) has been used connected in series with the bass driver. A series capacitor (C2) 'rolls in' the mid-range in the same region. A simple inductor-capacitor high pass filter (L1-C1) rolls in the tweeter at around 4.5 kHz.

A fairly simple crossover network like this avoids difficulties with phase response and driver-network interactions, resulting in no 'little surprises' in the general response of the loudspeaker.

The resistors connected to the mid-range and tweeter are there to attenuate their output levels so that the three drivers have generally equal output. The mid-range and tweeter are more sensitive than the bass driver employed.

The capacitors used are 'bipolar' electrolytic types. That is, they are manufactured so that they are not polarised — no positive or negative terminal. This allows them to be used in purely ac applications.

Construction

The box supplied by Dick Smith Electronics is generally constructed of 15 mm chipboard with a base made from 18 mm chipboard — the base is likely to take more punishment during handling! The outside faces are covered in plastic wood veneer. The front panel, with the three cutouts for mounting the drivers, is set flush with the front of the cabinet and the front surface is covered in black vinyl, for appearance's sake.

Four 'sockets' are set into the front panel near the corners. The grille cloth is stretched over a polycarbonate moulding which has four pins projecting from the rear that set into the sockets on the front panel, providing a simple, yet effective, method of securing the front grille.

The rear panel is recessed slightly. The crossover network pc board is screwed on the inside to this and speaker connecting terminals pass through from the outer rear.

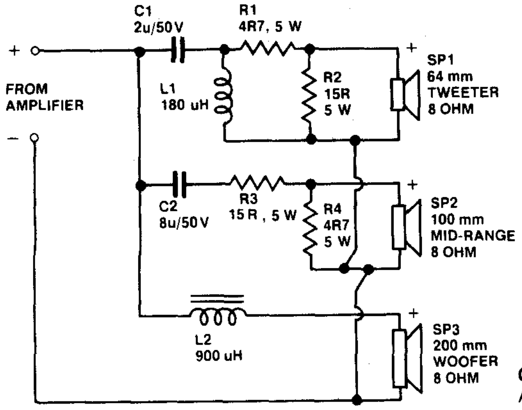
As Dick Smith Electronics will be providing precut box panels, construction is quite simple. Fold the top-bottom-side panels around the rear panel, running generous quantities of PVA glue (Aquadhere, or similar) in the folds as you go. Position the rear panel so that it's recessed about 10 mm (not critical) from the rear of the box and run a bead of glue around the joint on the *inside* of the cabinet. Small 'chocks' are used to strengthen the rear panel and these should be positioned around the joint on all four sides and thoroughly glued in place. Lay the box on its back to do this and leave it there while the glue cures.

When the box is ready to handle again, take some sealing or caulking compound (Silastic is very good) and run a bead around all the joints. All joints must be

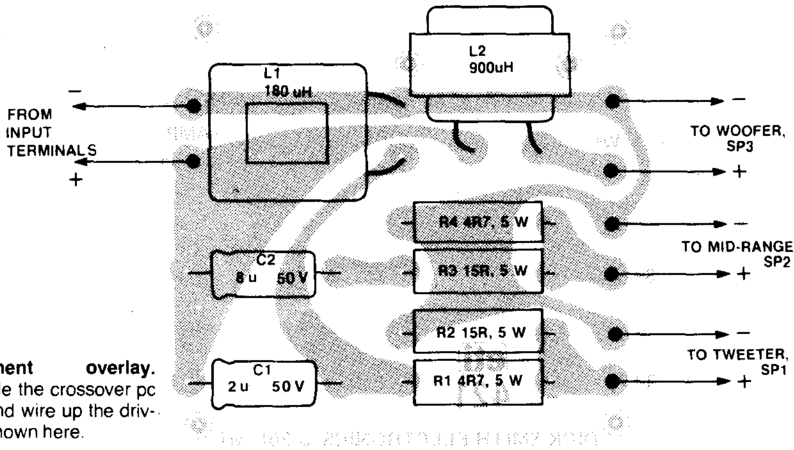
PARTS LIST ETI-421

Resistors	all 5 W, 10%
R1, R4	4R7
R2, R3	15R
Capacitors	
C1	2u/50 V non-polarised electro.
C2	8u/50 V non-polarised electro.
Inductors	
L1	180 uH air-cored
L2	900 uH iron-cored, open-end
Miscellaneous	
SP1	8 ohm, 64 mm tweeter (parg of D.S.E. C-2046)
SP2	8 ohm 100 mm mid-range (part of D.S.E. C-2046)
SP3	8 ohm 200 mm woofer (part of D.S.E. C-2046)

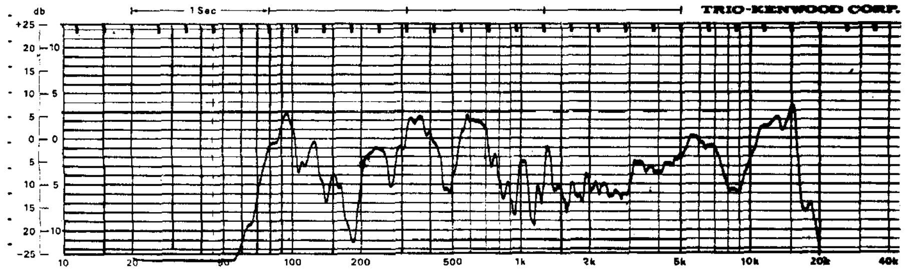
ETI-421 pc board for crossover; box to dimensions in drawings; speaker terminals; wire, speaker box lining, etc.



Circuit. How the drivers and crossover are connected.



Component overlay. Assemble the crossover pc board and wire up the drivers as shown here.



The result. No speaker has a truly 'flat' response and this speaker is no exception! The result is quite good with excursions no more than +7 dB, −6 dB from a median line.

airtight if the pressure box is to work properly.

Now, run a generous amount of glue around the rabbet at the front of the box, where the front panel will set in. Make sure it's generous as this will have to seal the front panel. Run more glue around the edges of the front panel and then set it in place. Wipe off any excess glue that may be on the outside faces of the box. Allow the glue to cure before proceeding.

Stand the box on its top and assemble the base, carefully gluing it in place. Run the glue on the mating surfaces of the base pieces. Leave the box while the glue cures.

Now for the crossover. This is assembled on a small pc board. The overlay diagram shows the general layout. It can be constructed in any order, but I'd suggest you start by mounting the resistors and capacitors first. Stand the resistors a few millimetres off the board so that heat can escape. The resistors will sure get hot at party time!

Mount the inductors last of all. Both are supplied prewound. The 900 uH inductor has a set of 'E' laminations to obtain the inductance required on the small bobbin. This inductor is secured to the board passing the lugs through two holes drilled in the board for them, and bending over them at the rear. The other inductor is simply wound on a bobbin which can be glued to the board in the place indicated.

Solder pc stakes in place for terminating the input and speaker wires.

Now, back to the cabinets. The speaker terminals need to be mounted. Two holes are drilled in the rear of the cabinet somewhere near the middle. The lugs of the speaker terminals will pass through these. But first, solder a 400 mm length of *red* insulated hookup wire (heavy duty, 24 x 0.2 mm, wire is best) to the terminal marked with a *red spot*. This is the "positive" terminal (marked with a plus on the circuit). Solder a 400 mm length of *black* insulated hookup wire to the other terminal.

Pass the wires almost right through the holes in the cabinet rear and then put caulking compound in the holes to seal them. Press the terminal strip in place and screw it down. Go to the inside of the cabinet and caulk the holes again just to be sure.

Wires should now be soldered to each driver. Use heavy duty hookup wire (24 x 0.2 mm, at least). Each driver will have the positive terminal marked in some way — maybe with a '+', with a red spot or with a red-coloured insulating washer. Attach a 400 mm length of *black* insulated hookup wire to each driver's negative terminal. Then, attach a 400 mm length of coloured wire to each driver's positive terminal — using a different colour for each driver (say, white for the tweeter, yellow for the midrange and blue for the woofer).

Next, place the crossover pc board on the inside of the rear panel, opposite the woofer's hole (it's easier to get at through the large hole). Screw it in place. Solder the input wires to the two input terminals on the board. *Be careful to observe the correct polarity.* Place each driver on the front face, adjacent to its mounting hole. Pass the wires from each driver, through its mounting hole, and solder them to their respective terminations on the crossover board. Be careful, once again, to *observe correct polarity.*

Now, completely stuff the inside of the cabinet with innerbond.

Before screwing each driver in place, attach adhesive foam tape (available from hardware stores, used for sealing cupboards, etc) around the lip of each driver hole so that a good seal is made. Then screw the drivers in place.

Powering up

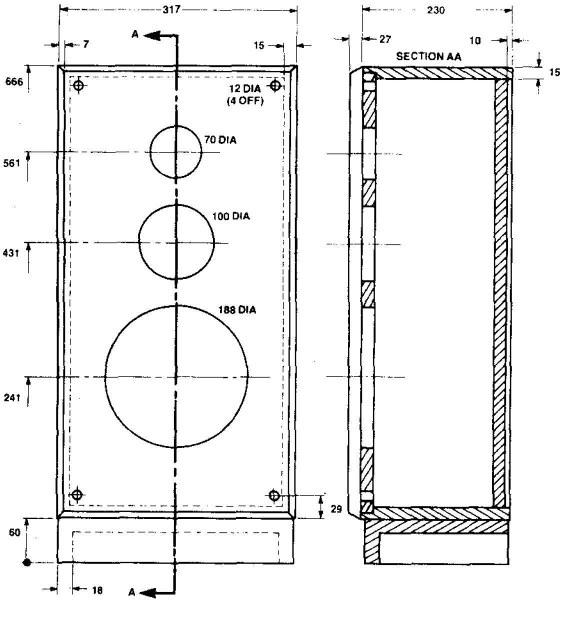
Before connecting the speakers to an amplifier, take a *single* 1.5 V cell and briefly touch its terminals to each speaker's input terminals — positive to the terminal marked with a red spot. The woofer cone should move *forward* as you do this, and the loudspeaker should make a loud thump. *Do not* use a battery any larger than a 1.5 V cell for this test or you could damage the woofer.

If all is well, connect the speakers to an amplifier, select your favourite record or tape, turn the volume up slowly and sit back and enjoy the satisfaction of having built your own speakers!

A word of caution. These speakers should be able to comfortably handle 40 W of power. This is not a peak rating. In fact, transients up to 100 W should cause no ill effects. The most dangerous condition for using any speaker is when the amplifier is clipping heavily. Under these conditions, the amplifier's output approaches dc and even a 20 W amp is capable of doing irreparable damage if clipping operation is prolonged.

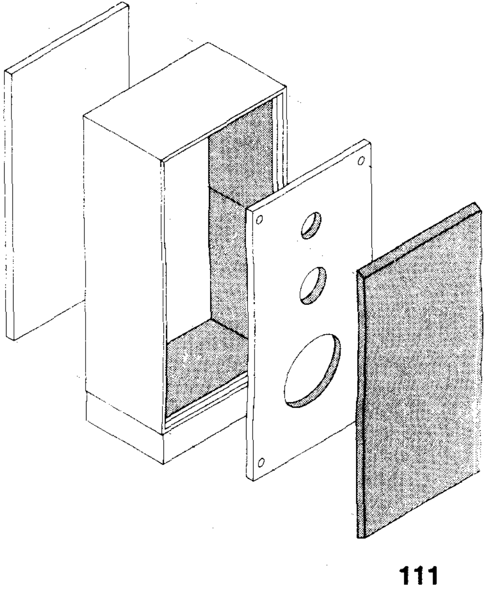
For safety's sake (and to save the expense of replacing drivers), you might add our Signal-Powered Loudspeaker Protector, ETI-494, published in the October 1982 issue. This will protect your speakers from both overpower abuse and from amplifier faults that might apply dc to the speakers.

Good listening.

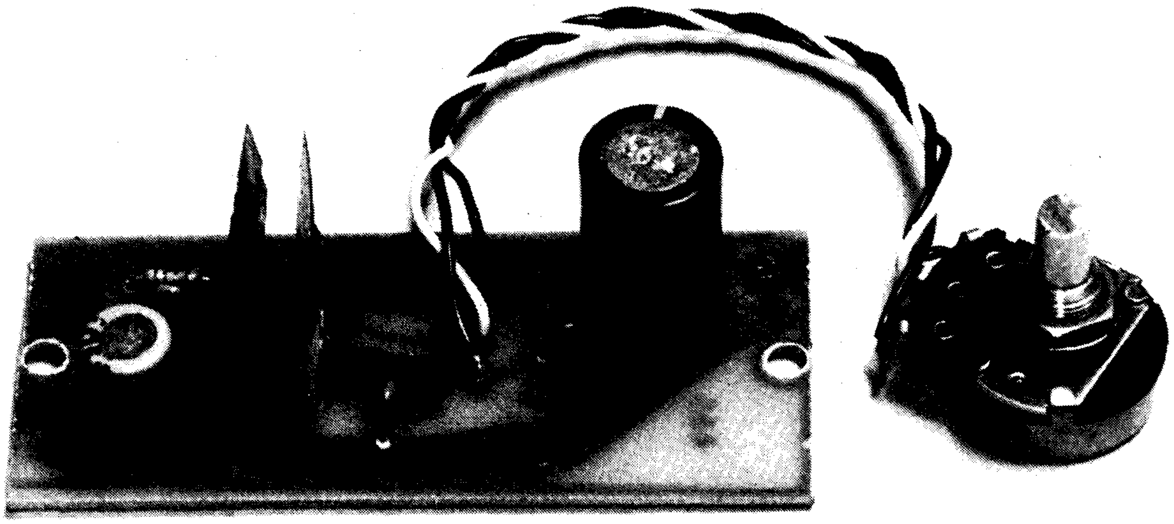


Cabinet details. All the cabinet dimensions are shown on the left and an exploded view of the assembly is shown at right. Dick Smith Electronics supplies precut panels with kits, which makes the assembly job a breeze. The front grille is an open weave black cloth stretched over a polycarbonate frame.

ALL DIMENSIONS IN mm
NB: FRONT GRILLE REMOVED TO SHOW DRIVER POSITIONS
BOX MADE OF 15 mm CHIPBOARD
BASE MADE OF 18 mm CHIPBOARD



Project 464



A general purpose IC audio amplifier module

This is an ideal project for the beginner. In fact, most constructors will find it handy to have at least one around. A general purpose small audio amplifier finds many useful applications. Just two described here are an intercom and a 'baby minder'.

Geoff Nicholls

A VERY USEFUL object for any electronics enthusiast to have around is a simple audio amplifier. It can be used to test the operation of many circuits or employed in some practical item of equipment — such as an intercom.

This simple, yet versatile, module is easy to construct and can be powered from a variety of supply voltages, depending on your application. It will drive loudspeakers of 4, 8 or 16 ohms impedance and can deliver a maximum output of five watts.

The project has been designed around an integrated circuit audio power amplifier, the LM380 (from National Semiconductor) or the uA380 (from Fairchild). This is quite a versatile little IC and, using it, an audio amplifier is very simple indeed to make.

The '380 is generally available in a 14-pin dual-in-line package, and this is what I have employed here. An 8-pin version is available, but cannot be used in the pc board I have designed for this project. Pins 3, 4 and 5 plus 10, 11 and 12 of the 14-pin package are all connected together by a copper bar inside the '380 package, on which the chip is mounted. These pins can be soldered to a large area of copper on the pc board to act as a heatsink in relatively low power applications.

Where the full power output capability of the '380 may be used, copper shim or tinplate heatsink 'flags' are soldered to these pins to get rid of more heat and keep the temperature of the IC down.

The '380 has a gain of 50 times. That is, it will amplify the input signal level by 50, which is a gain of 34 decibels (34 dB). That is:

$$\begin{aligned}\text{Gain in dB} &= 20 \log_{10} (50)\\ &= 20 \times 1.7\\ &= 34 \text{ dB.}\end{aligned}$$

The gain of the '380 is fixed by the manufacturer. But what if you want a volume control, as is so often necessary on an audio amplifier? That can be simply arranged by connecting a potentiometer as a voltage divider to the input of the IC. You can see how that's done from the circuit and construction diagrams.

You can use this project to amplify the output of a crystal set or one-transistor receiver to loudspeaker level simply by connecting the output directly to the input of the module.

You can make a 'baby minder' — for keeping an ear on the baby in its cot, from another room — as shown later in this article, or you can make a simple intercom — which is also illustrated later. Another article in this issue shows how to use the module in a loudhailer.

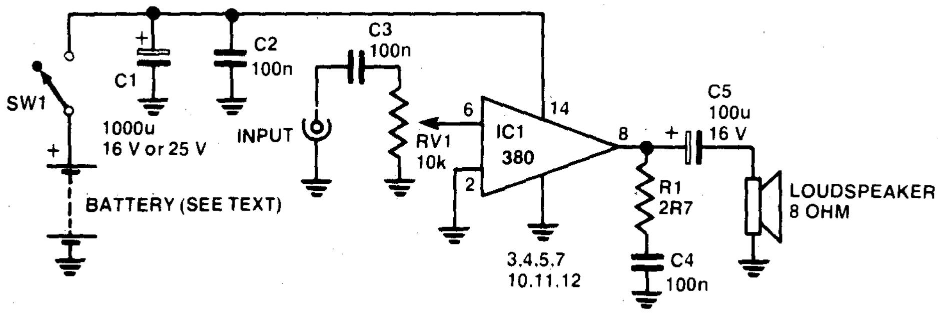
Right, let's get down to the business of building it.

Construction

As you can see from the overlay and wiring diagrams, there's very little to it. Start with the pc board. Whether you've made your own or purchased one, just give it a quick check-over to make sure all the holes are drilled correctly, that there are no small copper 'bridges' between closely spaced tracks (particularly between the IC pins) and no tiny cracks in any tracks. It's unlikely you'll have trouble, but it's always a good idea to check, *before* you run into trouble!

Note that mounting holes are located at either end of the board. These should be drilled to suit a 4 BA bolt, or whatever size you are using.

You can commence assembling the board by soldering resistor R1 in place, followed by capacitors C2, C3 and C4. All components



HOW IT WORKS — ETI-464

There's not much you can say about this! The whole job is done by the '380 IC audio power amplifier. The input is coupled to the '380 via a capacitor (C3) and the volume control, RV1. The latter is just a voltage divider, applying less or more voltage to the IC's input as the potentiometer is varied, thus varying the volume.

The output of IC1, pin 8, is biased at half the supply rail (e.g: it will be at 4.5 V if the supply is 9 V). For this reason, the output is capacitively coupled to the loudspeaker via a large value electrolytic capacitor, C5. This presents a low impedance in series with the loudspeaker, which is a relatively low impedance device.

Any tendency to instability of the amplifier is suppressed by the network of R1-C4 connected from the output to common.

The supply rail is bypassed by an electrolytic capacitor, C1, at the low frequencies, and a greencap or ceramic capacitor, C2, at the higher audio frequencies.

Note that provision has been made on the pc board for powering an electret type microphone, simply by adding a resistor adjacent to C3.

mount on the non-copper side of the board. Next identify the positive and negative leads of the two electrolytic capacitors. These are 'polarised' devices and can only go in one way. Solder them in place, putting the positive lead of each in the hole marked with a '+' on the overlay diagram.

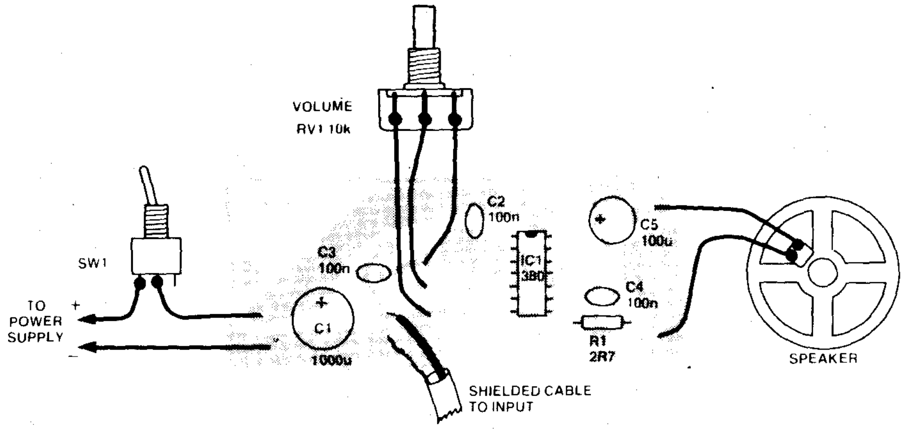
The '380 IC can be soldered in place next. Make sure you place it in the board the right way round before soldering the pins. Do not use an IC socket as the board is designed to act partially as a heatsink and pins 3,4,5,10, 11 and 12 *must* be soldered to the copper area for this purpose.

The heatsink flags can be constructed next if you need to use them. Use heavy gauge copper 'shim' or tinplate sheet (obtainable at hardware and motor spares stores). Two are required and the dimensions and cutting details are shown in the accompanying diagram.

General details for wiring up the speaker, volume control and an on/off switch are also provided with the overlay diagram. Note that the input lead should be run in shielded cable, in general, especially if this lead needs to be more than 300 mm or so long. This prevents hum pickup from house mains wiring. For short runs, a pair of tightly twisted hookup wires will suffice.

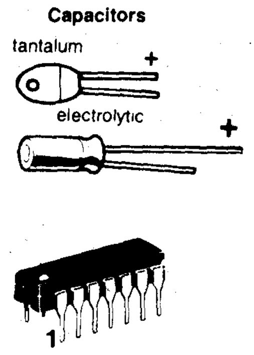
This module will drive any size loudspeaker, from the tiny 50 mm 'transistor radio' types to 400 mm diameter 'monsters'. In fact, the larger a loudspeaker, the more sensitive it's likely to be and the louder it will sound! You don't need more power to drive a larger loudspeaker, despite what you might at first think.

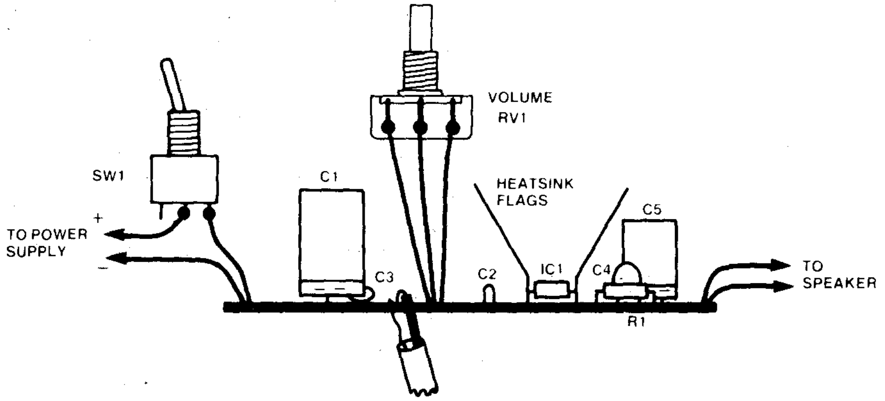
The bigger loudspeakers generally have a more powerful magnet than the smaller types. This makes them more sensitive to the currents flowing in the voice coil. This and the larger cone combine to produce a louder sound. ▶



Overlay and wiring diagram. Showing component placement and general wiring details.

COMPONENT PINOUTS





Side view. Showing assembly of the heatsink flags.

PARTS LIST — ETI-464

Resistors	all ¼ or ½ W/5%
R1	2R7
RV1	10k log. pot.
Capacitors	
C1	1000u/16 VW or 25 VW RB electro.
C2,C4	100n ceramic bypass
C3	100n greencap
C5	100u/16 VW RB electro.
Semiconductors	
IC1	LM380

Miscellaneous

ETI-464 pc board; SPST switch; shielded cable; wire, etc.

Price estimate $7-$8

Testing it

The easiest way to test it is simply to connect a 9 V battery to the module and turn up the volume control. Then, touch your finger to the 'top' end of the volume control — the right hand lug when looking at the rear of the pot. You should hear hum and noise, or perhaps a loud 'blurting' sound. If not, check that the battery is connected the right way round and that the speaker and volume control wires are all intact and correct. Check that you have the IC correctly orientated.

Connecting a 9 V battery in reverse to the module is unlikely to destroy the IC, but any higher supply voltage connected in reverse sure will, so watch this point.

If the amplifier tends to be unstable, 'squealing' or otherwise 'acting up', try connecting a 4u7/16 V tantalum capacitor between pin 1 of the IC and the adjacent grounded area of the pc board, directly on the underside of the board. The positive lead goes to pin 1. Keep the lead lengths short. This should cure it.

Always keep the amplifier's input leads away from the speaker leads, to avoid feedback which may result in 'howl round' — an uncomfortable whistling or howling sound that is affected by moving the leads.

Power supplies

This module can be powered form batteries, a suitable plugpack or transformer and rectifier to suit yourself. The power output depends on the supply voltage and the speaker impedance. As stated earlier, the '380 can drive 4, 8 or 16 ohm speakers. By far the better speaker to use is an 8 ohm impedance type. Fortunately, they're also the most common type.

Powered from a nine volt battery, you will get about half a watt (500 mW) output, which is more than adequate for 'personal' listening stations; e.g: providing loudspeaker output from a crystal set or one-transistor radio, etc. The power dissipated by the IC under these circumstances is about three quarters of a watt maximum, so no heatsink flags would be necessary. The module draws only about 5 mA with no signal (called the 'quiescent current').

The *absolute maximum* supply voltage the IC will tolerate is 22 V. With an 8 ohm speaker, the project will deliver five watts output, which is remarkably loud! Under these circumstances, the power dissipated by the '380 will be a little over three watts maximum and heatsink flags will definitely be necessary. The quiescent current is about 8 mA on a 22 V supply.

A plugpack or transformer and rectifier supply suitable for powering this module should provide 12 Vdc at 200 mA or so. Using such a supply, the project will deliver about one to 1½ watts to an eight ohm speaker, which is quite suitable for an intercom, for example. The heatsink flags are not entirely necessary with this sort of application, especially in an intercom where the amplifier is only used intermittently.

Two nine volt batteries connected in series will supply 18 Vdc or so to the module, which will deliver about three watts to an 8 ohm speaker. Heatsink flags are necessary in this case. Note that, when using a 4 ohm speaker, the supply should not exceed 15 volts.

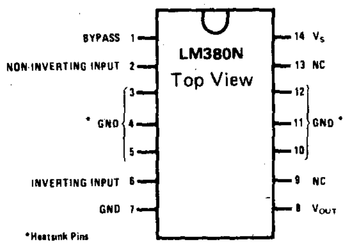
LM380 audio power amplifier

general description

The LM380 is a power audio amplifier for consumer application. In order to hold system cost to a minimum, gain is internally fixed at 34 dB. A unique input stage allows inputs to be ground referenced. The output is automatically self entering to one half the supply voltage.

The output is short circuit proof with internal thermal limiting. The package outline is standard dual-in-line. A copper lead frame is used with the center three pins on either side comprising a heat sink. This makes the device easy to use in standard p-c layout.

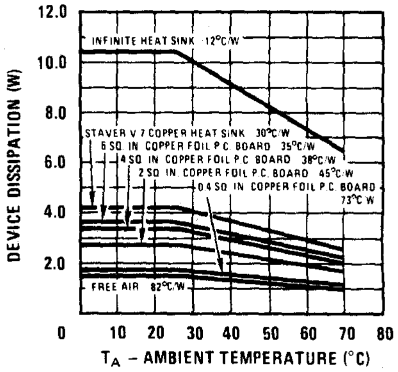
Uses include simple phonograph amplifiers, intercoms, line drivers, teaching machine outputs, alarms, ultrasonic drivers, TV sound systems, AM-FM radio, small servo drivers, power converters,etc.



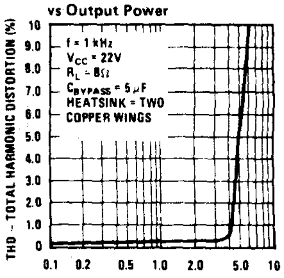
features

- Wide supply voltage range
- Voltage gain fixed at 50
- High peak current capability
- Input referenced to GND
- High input impedance
- Low distortion
- Quiescent output voltage is at one-half of the supply voltage
- Standard dual-in-line package

Device Dissipation vs Ambient Temperature



Total Harmonic Distortion vs Output Power



absolute maximum ratings

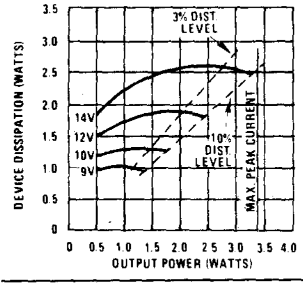
Supply Voltage	22V
Peak Current	1.3A
Package Dissipation 14-Pin DIP (Notes 6 and 7)	10W
Input Voltage	±0.5V
Storage Temperature	-65°C to +150°C
Operating Temperature	0°C to +70°C
Junction Temperature	+150°C
Lead Temperature (Soldering, 10 sec)	+300°C

electrical characteristics

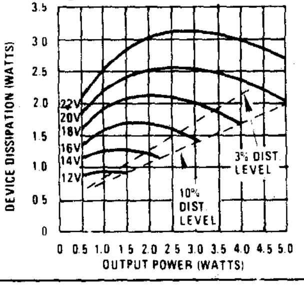
Note 1: V_S = 18V and T_A = 25°C unless otherwise specified.

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Output Power	$P_{OUT(RMS)}$	R_L = 8Ω, THD = 3%	2.5			W
Gain	A_V		40	50	60	V/V
Output Voltage Swing	V_{OUT}	R_L = 8Ω		14		V_{pp}
Input Resistance	Z_{IN}			150k		Ω
Total Harmonic Distortion	THD			0.2		%
Power Supply Rejection Ratio	PSRR			38		dB
Supply Voltage	V_S		8		22	V
Bandwidth	BW	P_{OUT} = 2W, R_L = 8Ω		100k		Hz
Quiescent Supply Current	I_Q			7	25	mA
Quiescent Output Voltage	V_{OUTQ}		8	9.0	10	V
Bias Current	I_{BIAS}	Inputs Floating		100		nA
Short Circuit Current	I_{SC}			1.3		A

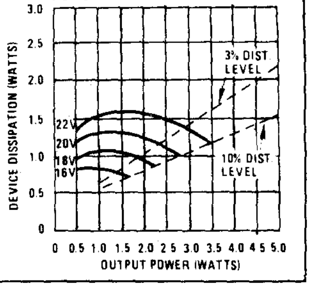
Device Dissipation vs Output Power — 4Ω Load



Device Dissipation vs Output Power — 8Ω Load



Device Dissipation vs Output Power — 16Ω Load



A 'baby minder'

You can 'keep an ear' on a baby asleep (or supposed to be!) in its cot in another room by organising some sort of microphone to pick up sounds from the baby's room to be amplified and heard in another room.

The general wiring diagram for a baby minder is shown in Figure 1. Here, a small 8 ohm loudspeaker is employed as a microphone — and they're remarkably effective. A transformer is needed to 'step up' the tiny voltages produced by the speaker-microphone. A suitable type is generally described as a 'transistor output transformer, 1k centre-tapped to 8 ohm'. Dick Smith Electronics lists a suitable type — cat. no. M-0216. Altronics have a similar one. Tandy lists one also, no. 273-1380.

The '8 ohm' side is connected to the speaker-microphone — this is the side with just two leads. The 1k side of the transformer is connected to the input of the module. Mount the transformer close to the module. The module could be mounted in a suitable cabinet with the speaker, volume controls and on/off switch mounted on the front.

The speaker-microphone could be mounted in a small jiffy box placed in a convenient position in the baby's room, near the cot. This connects to the amplifier via a length of 'twisted pair' cable or light 'figure-8' flex. Try and avoid running this lead adjacent to house mains wiring to avoid possible hum pickup.

I have specified an 8 ohm speaker as a microphone as it is of such a low impedance that the possibility of hum pickup on the cable between the microphone and the amplifier is greatly reduced.

You can either use a battery supply or a 12 Vdc plugpack.

Intercom

The general details for wiring a simple intercom are shown in Figure 2. You'll need two single-pole, double-throw (SPDT) toggle switches with a spring return. Double-pole types are also suitable, just use one side (e.g: C&K type 7208 or similar). You'll also need an M-0216 transformer, or similar, as for the Figure 1 circuit.

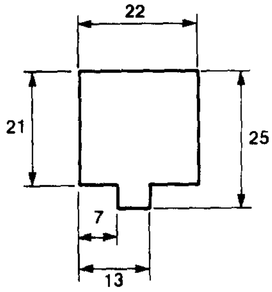
Two small 8 ohm speakers are used as both speaker and microphone at each end of the intercom.

A volume control is necessary on an intercom and a small 'trimpot' can be mounted on the pc board where the volume control connections are made. The hole spacings are suitably placed for soldering a common vertical mounting trimpot in place.Use one of the same value — i.e: 10k. Test out the intercom and set the volume control to suit yourself.

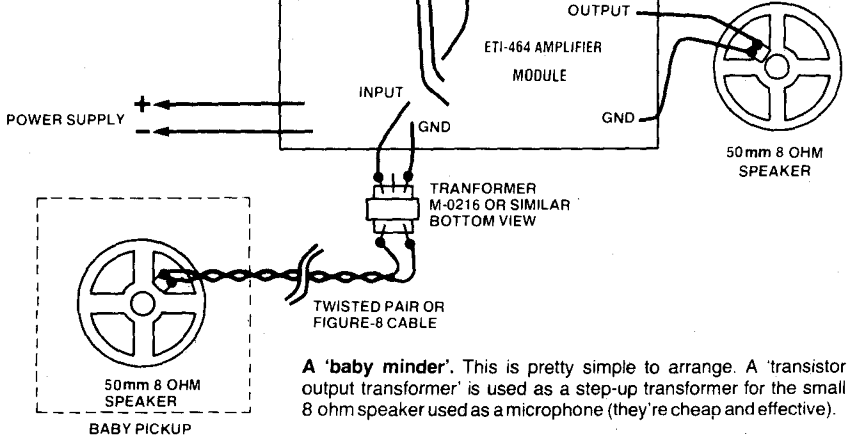
A suitable cable can be made by twisting together three strands of light hookup wire or buying a suitable length of light multicore cable. Note how the various common, or earth, connections are made to the one ground point on the pc board.

Conclusion

Well, I've described how to build yourself a general purpose audio amp module and how to use it in a couple of applications — the rest is up to you. Have fun! ●

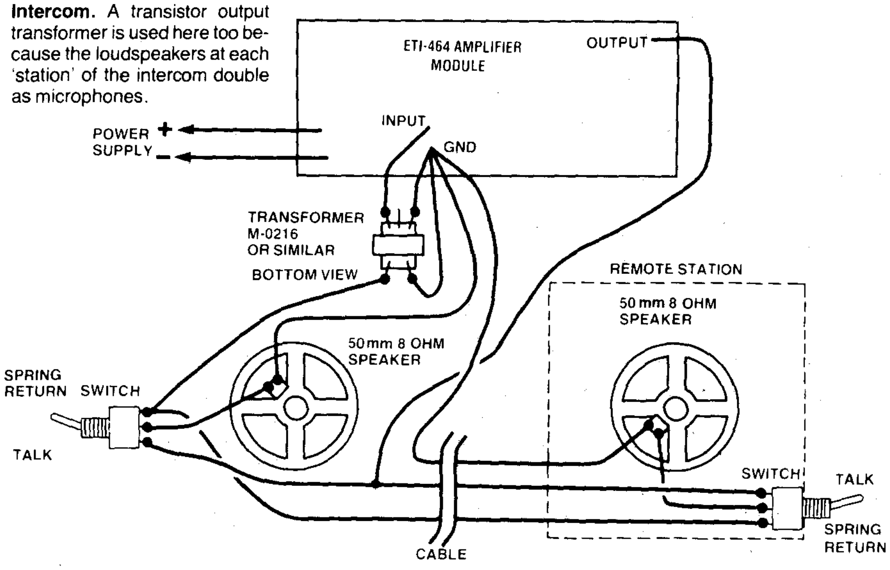


HEATSINK (TWO REQUIRED) TO BE ATTACHED TO EITHER SIDE OF IC AS SHOWN IN MAIN PICTURE. ALL DIMENSIONS IN mm

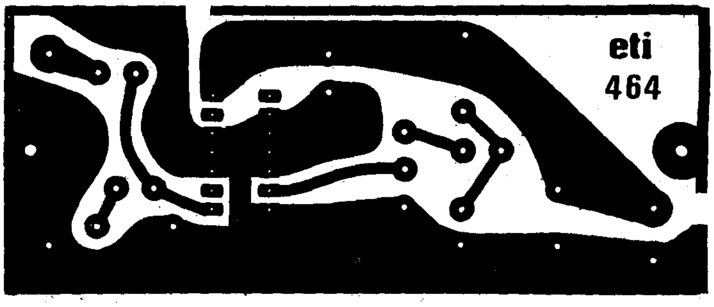


A 'baby minder'. This is pretty simple to arrange. A 'transistor output transformer' is used as a step-up transformer for the small 8 ohm speaker used as a microphone (they're cheap and effective).

Intercom. A transistor output transformer is used here too because the loudspeakers at each 'station' of the intercom double as microphones.



Printed circuit artwork. Full-size reproduction of the pc board layout



LED audio peak programme display

A 'universal' audio peak signal display, this simple project is cheap and easy to build. It features a 10-LED bargraph array and has thousands of applications as an add-on to a hi-fi system.

David Tilbrook

THIS PROJECT can be installed in any audio system to provide a simple visual indication of signal level either at the output of the preamp or at the output of the power amp. It features a 10-LED bargraph-type display that shows the peak signal level over a 30 dB range with a single moving dot or a varying bar of light.

There are a number of reasons for monitoring signal level in an audio amplifier system. Firstly, using a meter or other signal level monitor, you can set up a desired level and always return to the setting at a later time. Secondly, transients in programme material can easily exceed clipping levels in a preamp or power amp, causing distortion. A power amplifier driven heavily into clipping can deliver near-dc to a speaker, possibly causing damage.

The design of this display is adapted from the ETI-458 LED Level Meter which is used in the Series 5000 preamplifier. The ETI-458 features a simultaneous peak and average display with a row of 20 LEDs giving a 60 dB dynamic range. However, the design is more complicated than required for a general purpose level display and, as the pc board is quite large, it is difficult to install as an add-on to a hi-fi system, a mixer or such like.

A VU meter (VU stands for volume unit) is the generally-used 'work horse' audio level meter. It measures the signal level and displays it in decibels (dB). However, it is slow to respond and indicates something between the average and the real peak of the signal voltage so that all but the most repetitive peaks will be hidden. The VU meter could be indicating that the signal level is −15 dB when the peak transients of the signal are actually overloading the amplifier.

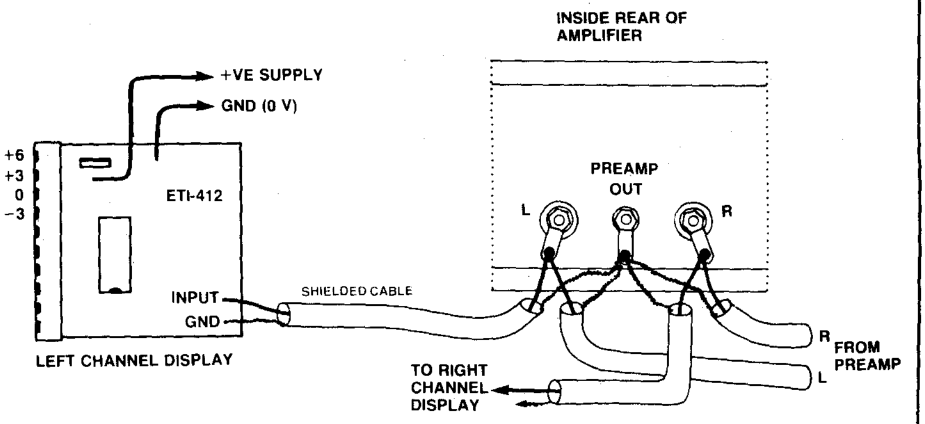


Figure 1. The peak programme display can be hooked up to the hi-fi system to monitor the output of the preamplifier.

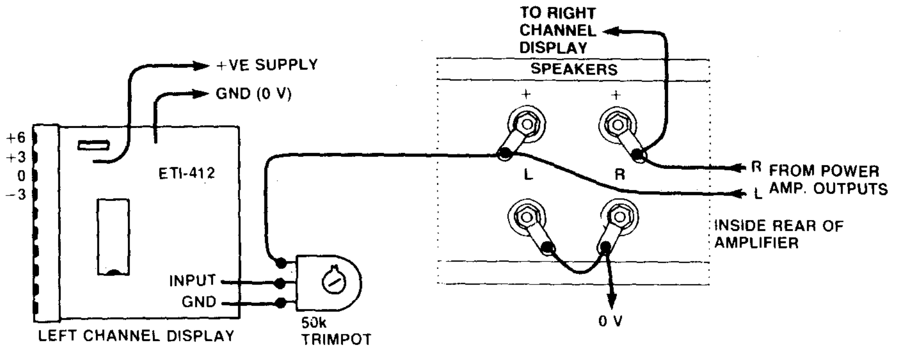
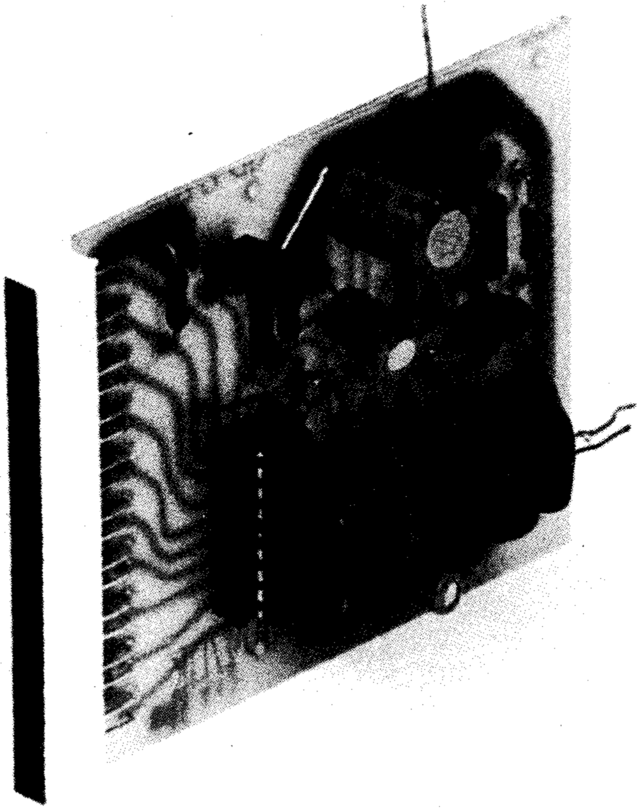


Figure 2. When monitoring the output of the power amplifier the display can be set to indicate the rated power output of the amplifier.



Another disadvantage of most VU meters is their limited dynamic range, being only about 20 dB, as it is a linear analogue meter and has a non-linear scale cramped at one end.

The ETI-412 has a logarithmic scale from −21 dB to +6 dB. As the ear responds logarithmically you need a logarithmic response from a meter. A perceived doubling of loudness is actually a 10 dB change in the sound level.

There are several places where this peak programme display can be connected in a hi-fi system but it is usually used to monitor the output of the preamplifier. It can then be set up so the point where the power amplifier commences clipping will be indicated at the top of the scale.

If you know that the headroom of the amplifier is, for example 3 dB, you can set it up so that the peak transients only go up to the +3 dB level on the display. If the volume is so loud that the level is peaking at +6 dB then you know that the amplifier is being driven into clipping. If you don't have a meter to indicate the peak signal level your ears will tell you that something is wrong as the distortion will be very obvious.

If the amplifier is clipping for a significant proportion of the time the speakers may blow up. While it is simpler to just build a clipping indicator, it is also useful to know something of the dynamics of the signal.

The display could also be used to monitor the output of the power amplifier. It could be set so that the 0 dB level on the display indicates the rated power output of the amplifier.

The display will also be useful for setting signal levels when taping. The advantage of using a peak signal indicating meter when tape recording means you can avoid overloading the tape and the consequent distortion.

The LED display has 3 dB between steps but all you need is a visual indication so a continuous scale is not necessary.

When you are wiring up the circuit it can be set for either a bar or dot display. As the circuit is designed it does not have a switch, but you could add a switch to the circuit so that it is possible to switch from bar to dot mode.

The peak rectifier system used in the ETI-458 LED Level Meter is used in this project. The output of the full wave rectifier, IC1, is fed to a peak follower formed by IC2 and its associated components.

The peak follower has a rapid attack/slow decay characteristic so that it responds quickly to any transients but decays slowly so the display 'hangs on' enabling you to see it easily.

The output from the peak follower goes to IC3, LM3915, which is the LED bargraph driver. The output of IC3 drives the 10-LED display. This was supplied by Altronics and we chose it rather than using separate LEDs as it is easier to use and looks better. ▶

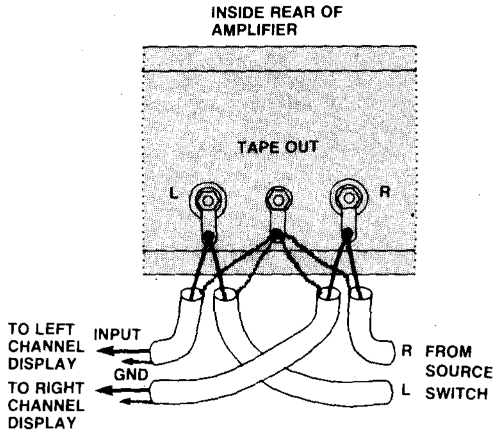
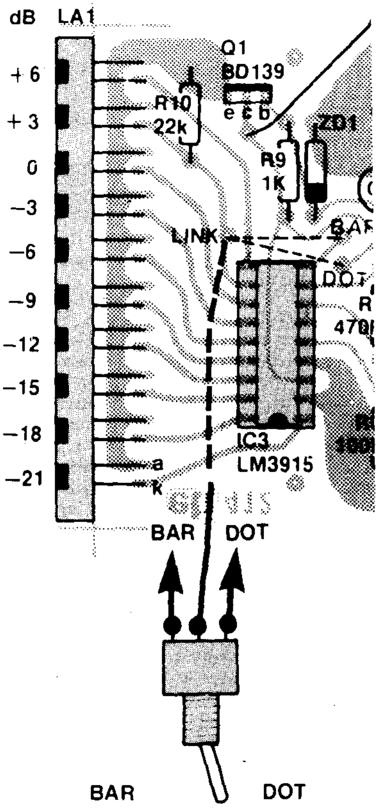
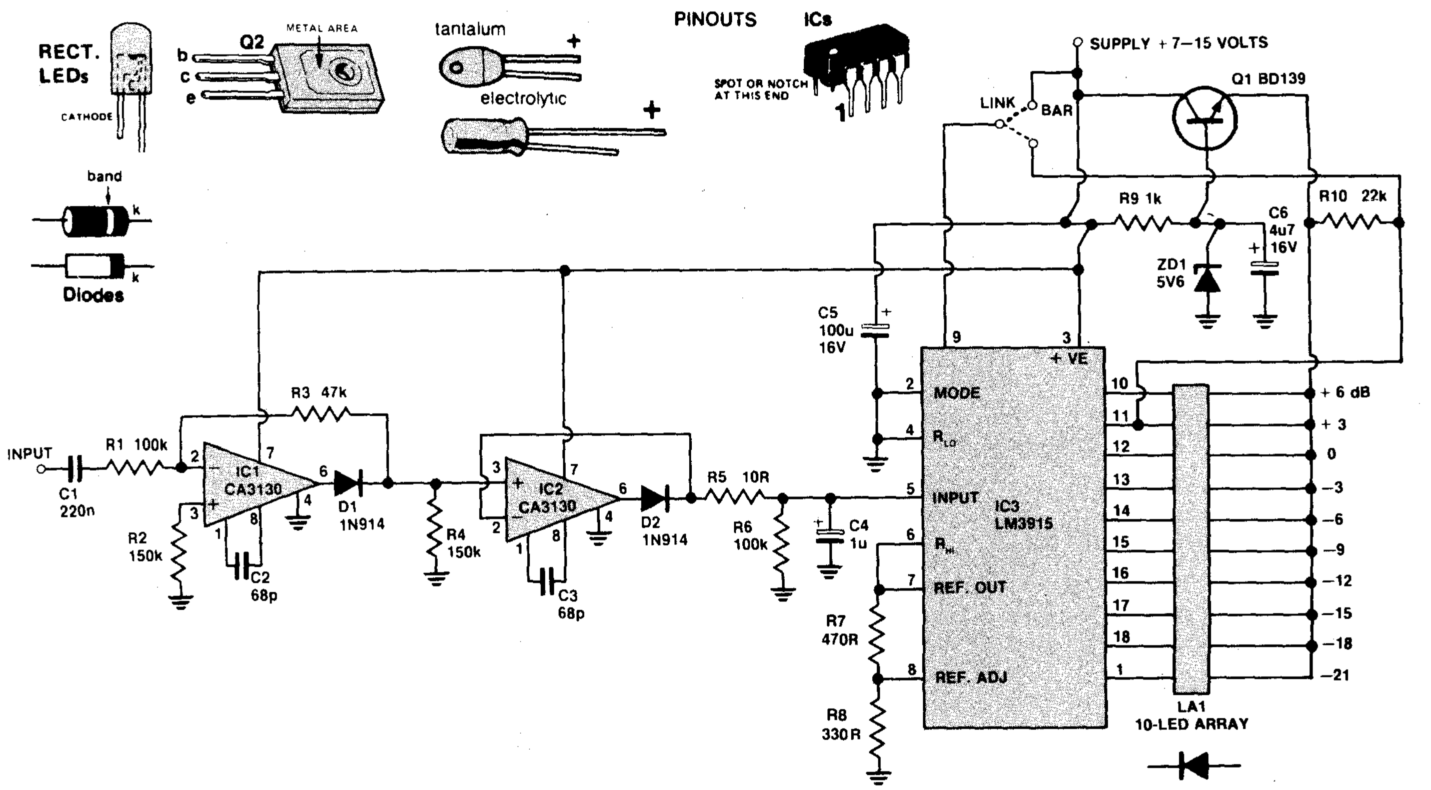


Figure 3. The project can be used to monitor the signal level output to a tape recorder so that you can avoid tape overload.



Bar/dot switch. If you like, adding a switch as shown here permits switching between a bar mode display and a dot mode. The pole of a single-pole, single throw (SPST) switch is wired to pin 11 of IC3 and the two contacts to the pads marked 'bar' and 'dot' on the component overlay.



Construction

As you can see from the overlay, the pc board layout is very simple. Before you get carried away with soldering, examine the board very carefully. Regardless of whether you made the pc board yourself or you purchased it, check to make sure that there are no small copper 'bridges' between closely spaced tracks (particularly between IC pins) and no tiny cracks in the tracks. Also make sure that all the holes are drilled correctly.

Those of you who want to use IC sockets in this project can do so.

You can start assembling the pc board by soldering the resistors in place. The three diodes can be soldered in position next, making sure that they are the right way around. If you are using IC sockets then solder them on the board next, otherwise, solder the ICs in next.

Then you can add the transistor BD139 and the capacitors, but check that the three electrolytic capacitors are correctly orientated.

The last thing to work out is which way the LED bargraph goes and solder it in place. The longer leads are the anodes which connect to the single common track along the edge of the board. If you do happen to connect the bargraph back-to-front it is unlikely anything will be damaged when you power it up.

Don't forget to wire up the link for either dot or bar display, depending on what you prefer. If you think that you might like to use either display then you can incorporate a switch into the circuit, as shown in the accompanying diagram.

HOW IT WORKS — ETI-412

The project is quite simple. There are three stages: a full wave rectifier or 'absolute value generator', a 'peak hold' circuit and a logarithmic display driver. The full wave rectifier produces the absolute positive value of the incoming signal and the peak hold circuit 'pumps up' a capacitor to the peak level, this capacitor only being slowly discharged so that the peak of the incoming signal is 'held' on to. The input of the display driver looks at the signal on the capacitor and drives a 10-LED array, each LED coming on in turn when the display driver's input is twice its previous value (ie: at 3 dB intervals).

The full wave rectifier comprises IC1, D1 and surrounding components. The input signal is coupled to the inverting input of IC1 via C1-R1. With a negative-going input signal, the stage acts as an inverting amplifier with a gain of a half determined by the ratio of R3 to R1. Thus, a positive-going output signal appears at the cathode of D1, half the level of the input.

When the input signal is positive-going, IC1's output is driven hard against its negative supply which is the 0 V rail here. Thus, the op-amp's output stage is turned off and, as it has a relatively high output impedance, and D1 is reverse-biased, the input signal will be just divided down by the potential divider formed by R1, R3 and R4. The voltage across R4 will be half the input voltage as R1 + R3 equals R4.

The signal across R4 is coupled to the non-inverting input of IC2, the peak hold stage. IC2 has a gain of one (unity) and the signal at the cathode of D2 will rapidly charge C4 via R5, a low value resistor. When the signal level on the output of IC2 falls below the voltage on C4, D2 will be reverse-biased and C4 will slowly discharge via R6, 'holding' the signal level on C4 long enough for your eyes to see the appropriate display LED lit.

The LM3915 display driver lights the LEDs at 3 dB intervals, according to the level presented at its input, which is across C4. The sensitivity of IC3 is set so that the 0 dB LED lights with 1 V peak at the input.

A regulated supply of 5 V is provided by a simple zener-referenced series regulator. This comprises Q1, ZD1, C6 and R9. The supply input can be anywhere between +7 V as a minimum and +15 V as a maximum (otherwise dissipation in Q1 becomes excessive).

The LM3915 can be arranged to provide either a 'dot' display, where just a single LED is turned on at a time, or a 'bar' display, where all the LEDs up to the peak are turned on. This is done by linking pin 11 to the positive supply rail for BAR mode or to pin 9, with a 22k bias resistor (R19) going to the +5 V supply, for DOT mode operation.

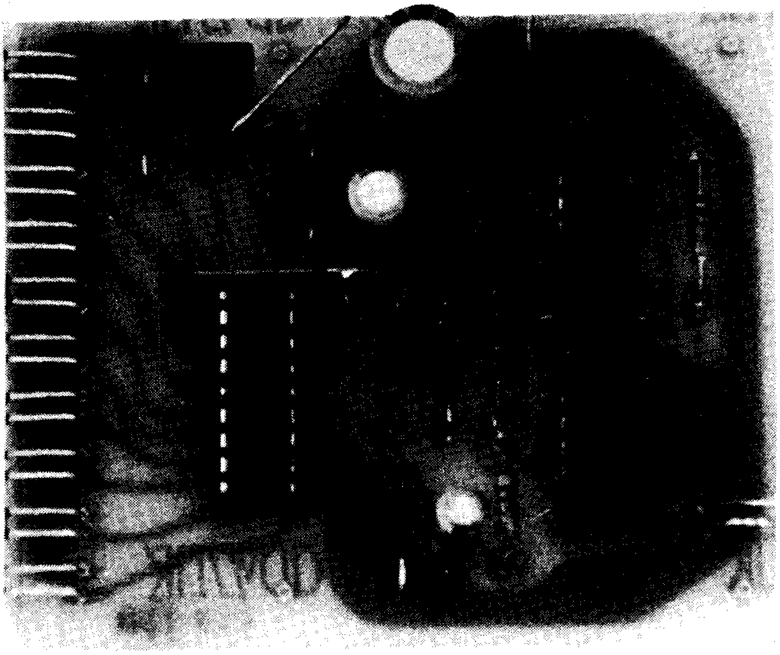
PARTS LIST ETI-412

Resistors	all ¼W, 5%
R1, R6	100k
R2, R4	150k
R3	47k
R5	10R
R7	470R
R8	330R
R9	1k
R10	22k
Capacitors	
C1	220n greencap
C2, C3	68p ceramic
C4	1µ/6 V low-leakage (RBLL) electro
C5	100µ/16 V single-ended electro
C6	4µ7/16 V single-ended electro
Semiconductors	
IC1, IC2	CA3130
IC3	LM3915
LA1	10-LED array (Altronics Z-0180)
Q1	BD139
ZD1	5V6

Miscellaneous

ETI-412 pc board; tinned copper wire.

Estimated cost: $15-$18

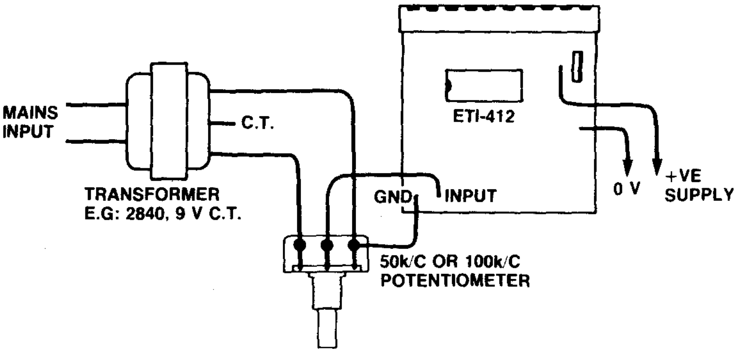


Testing it

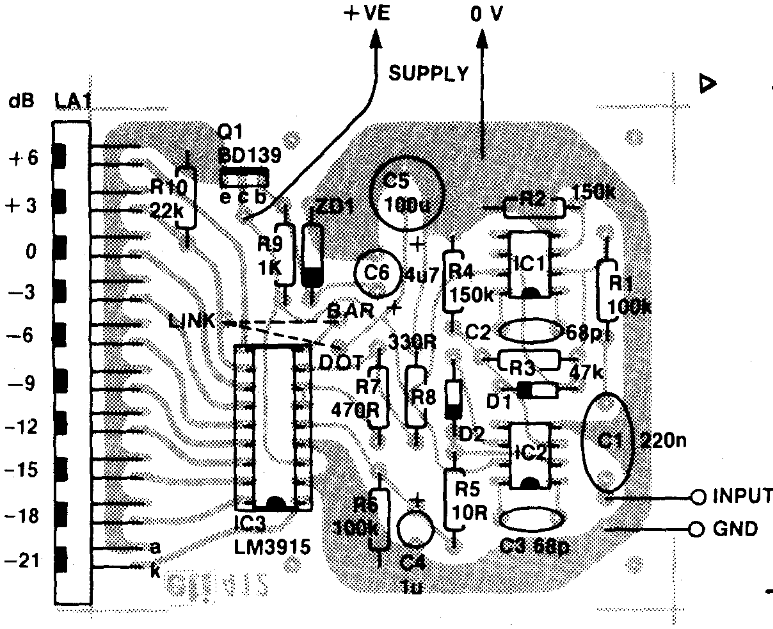
Test this project by attaching it to a +7 −15 V power supply and applying a signal to the input. The input signal can be supplied by an audio signal generator or from the output of a low voltage transformer.

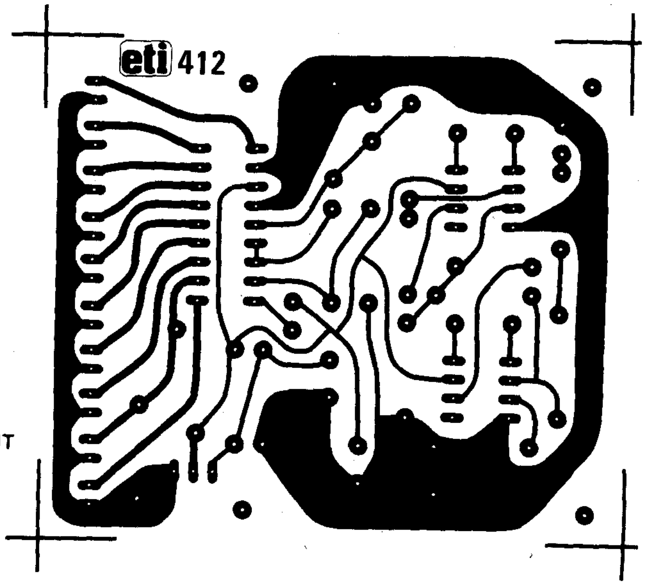
If you are going to use a transformer for this, connect a 100k potentiometer to the output of the transformer with the wiper of the potentiometer connected to the input of the project. If the meter is working properly the display on the LEDs should go up and down as you vary the level.

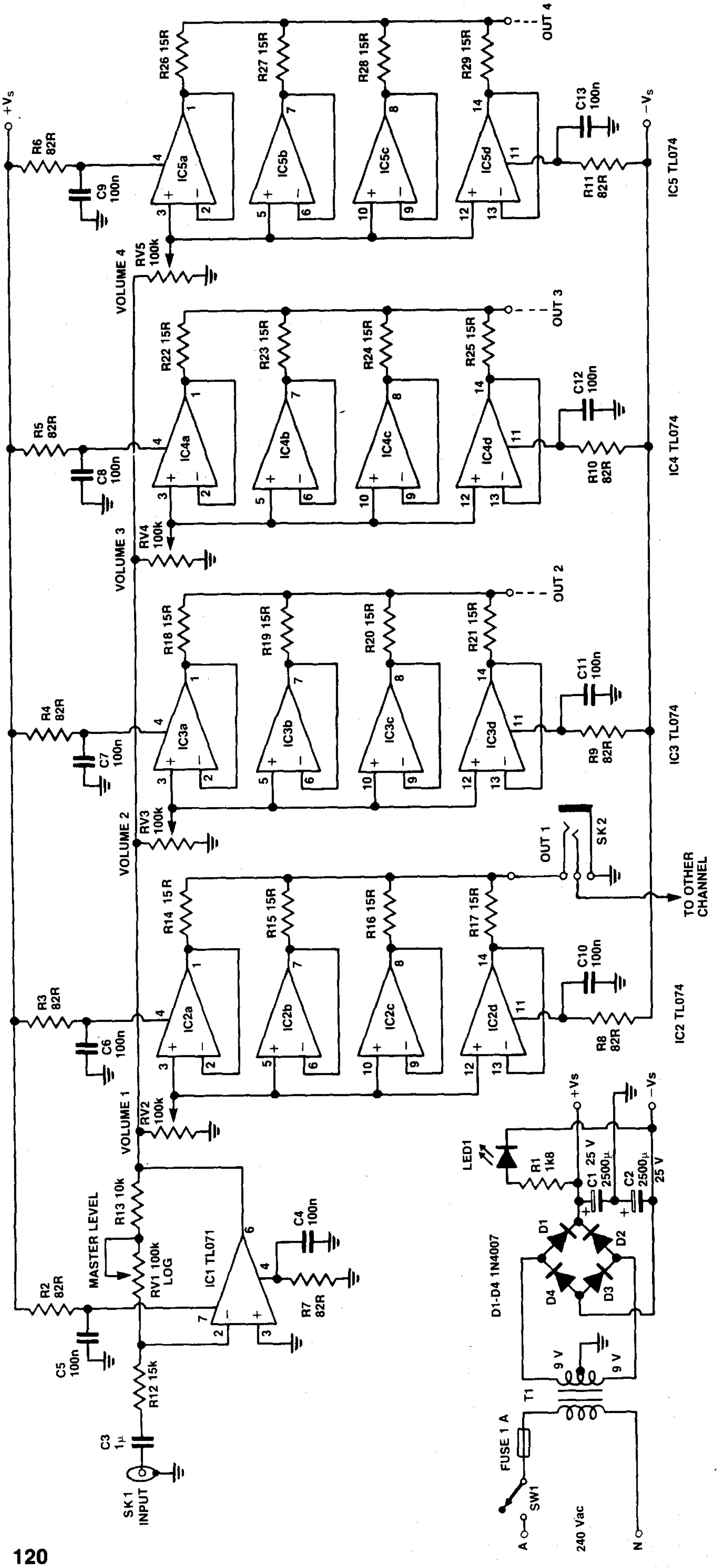
If the meter does not work at this stage check that all the components have been placed correctly on the board and orientated the right way around. ●


MAINS INPUT
C.T.
TRANSFORMER E.G: 2840, 9 V C.T.
ETI-412
GND
INPUT
0 V
+VE SUPPLY
50k/C OR 100k/C POTENTIOMETER

Test it out first. Before installing this project in your hi-fi system make sure that it works first in the illustrated test situation.







Project 462

IF YOU'RE INTO home recording studios but have those "lack of monitoring facility blues" or if you like listening to loud music late at night with a few friends but have the kind of neighbour that even your pet doberman is scared of, then here is the solution. This project allows up to four sets of headphones to be driven from the one source and provides separate volume control for each.

Design details

The circuit consists basically of an input gain stage which drives four voltage follower output stages. Both of the stages use op-amps from the TL07X series. The input uses a TL071 single op-amp and the output stages each use a TL074 quad op-amp package. Both of these ICs have the low noise and distortion figures and high slew rate necessary for audio work. Each headphone output has its own volume control which allows adjustment to suit individual users. An overall gain control allows the gain of the unit to be adjusted from −6 dB to +14 dB. This should provide enough cvntrol to be able to get a good headphone level from the headphone outlet of any cassette deck or amp.

The range of headphone impedances varies from around 8 ohms up to a few thousand ohms and there seems to be no real preference amongst manufacturers. This circuit will provide enough drive for any common impedance value headphone to be used.

HOW IT WORKS — ETI-462

Referring to the circuit diagram it can be seen that all of the output stages are identical, therefore only output one will be described.

IC1 is a TL071 single op-amp configured as an inverting amplifier stage. Potentiometer RV1 and resistor R13 form a variable gain control by changing the amount of negative feedback applied to the op amp. When RV1 is set to minimum, the gain is given by R13/R12. When RV1 is set to maximum the gain is (R13+RV1)/R12. This gives a −6 dB to +14 dB range with the specified components. Resistor R12 also sets the input resistance of the unit to 15k. This will provide negligible loading of the headphone outlet being used to drive the unit and allows units to be connected in parallel to provide more than four headphone outputs if needed.

The output if IC1 drives into the four parallel pots (RV2, RV3, RV4, RV5) which control the level of the signal fed to each of the driver stages. Looking at output stage 1, you can see that it consists of a TL074 quad op-amp package with all of the op-amps configured as voltage followers and connected in parallel. This acts as a *voltage follower with four* times the drive capability of the individual op-amps. Resistors R14, R15, R16 and R17 make sure that the current is summed evenly from each op-amp.

The power supply is *derived from* an 18V, centre-tapped transformer and is full wave rectified by D1-D4 and filtered by capacitors C1 and C2. This provides +ve and −ve 12 Vdc rails. The supply rails are coupled to each op-amp via an 82R *resistor and* a 100n bypass capacitor which isolates each stage and provides additional supply filtering.

Four channel stereo headphone driver

Robert Irwin

Received a noise abatement order lately for having the volume on the hi-fi too loud while you played Roxy Music's latest compact disc or the 1812 Overture? Maybe you've got your 'home studio' together but it lacks the monitoring facilities you need. This unit should fix all that.

The output stage uses a TL074 quad op-amp with all four op-amps configured as voltage followers and connected in parallel. this increases the drive capability of the op-amps to a point where it can drive the headphones directly without the need for a transistor output stage.

Construction

Start construction with the pc boards. Two identical boards are used except that the power supply components are omitted on one board. For the remainder of this article the board with the power supply components will be referred to as BOARD 1 and the board without these components will be referred to as BOARD 2.

Begin with Board 1. Give it a thorough visual inspection, checking tracks and holes to see that all's correct. Assemble the components as per the overlay diagram. Solder in all the resistors and capacitors first, followed by the diodes and then the ICs. Make sure that all polarised components (ICs, diedes, electrolytic capacitors, etc.) are positioned in the right orientation. Finally, solder into place the solder pegs or 'pc stakes' for attaching the wiring.

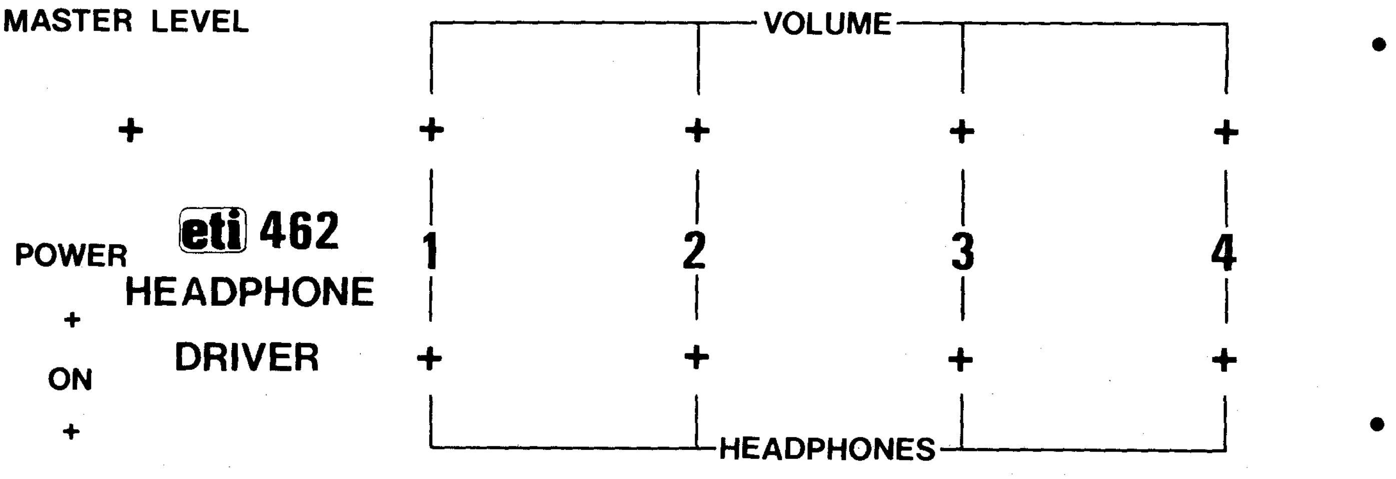
The construction of Board 2 is the same as Board 1 *except* that components D1 to D4, C1, C2 and R1 are omitted. Also, the three solder pegs which connect to the main transformer can be omitted as Board 2 derives its supply from the rails of Board 1 via connecting wires.

Once the pc boards are complete, the metalwork can be tackled. Disassemble the case and drill the front panel using the panel artwork below as a template. Remove all burrs from the holes after drilling.

Small pilot holes should now be drilled in the Scotchcal front panel label. See that you can line up the label using one edge being very careful to ensure that the pilot holes are approximately in the centre of the front panel holes. Remove the backing from the Scotchcal, attach it along the line-up edge you chose and smooth it down in place working from that edge. Once the Scotchcal label has been lined up and attached, the holes can be carefully cut out using a scalpel or a very sharp pointed knife. Take care not to rip the Scotchcal when doing this.

Next, the back panel can be drilled. Take the mains transformer and centre it on the back panel. Make sure that there is enough room on one side for the mains grommet and fuse holder and on the other side for the input jack. Mark the position of the transformer mounting holes and the hole centres for the mains grommet, fuse holder and input jack. These can now be drilled to the apppopriate sizes.

The pc boards should now be located. Take one board and position it on the floor on the box so that it is about 20 mm from the right hand side (looking from the front) and equidistant from the front and back panels. This will allow ample room for the mains wiring on the left hand side and also for the transformer on the back panel and pots on the front panel. Mark and drill the pc board mounting holes. Also on the floor ▶



of the box, holes should be drilled to mount a mains terminal block and earth lug. If a clamping type mains grommet isn't to be used then provision should be made for a mains cord clamp to be bolted to the floor as well. This is all done on the left hand side.

This completes the drilling. The case should now be reassembled but with the lid left off. You are now ready to mount the components. Firstly, take the four output jacks. Before mounting these you should attach 50 mm of hookup wire to each of the output terminals of the jacks (do not attach wires to the terminals yet). There is quite a bit of interwiring in this project so it is advisable to use a consistent colour code when attaching these wires. Once the jacks are mounted, the earth terminals should all be connected together and two wires soldered on to connect to the boards.

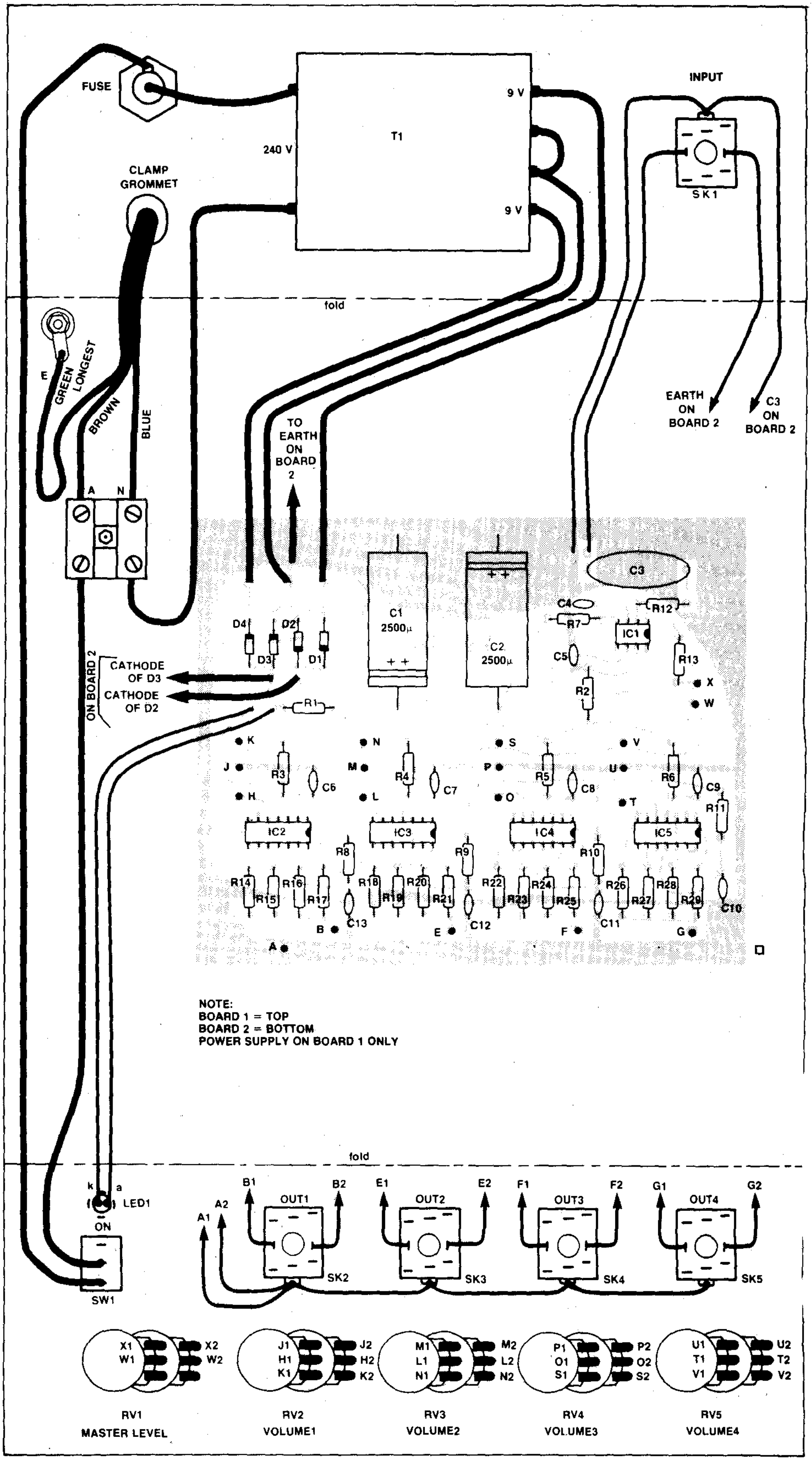
Next, 100 mm of wire should be attached to the four volume control pots. Once again a colour code should be used. Using a different colour for each of the three terminals on the pot and consistently wiring each pot the same way will greatly help when you come to wire the pc board. Once the wires have been attached, the pots can be mounted on the front panel. Make sure that none of the terminals are shorting out to the pot next to them. The master gain pot should be mounted and wired in the same way except that 200 mm lengths of wire are needed and only two of the terminals are used (see the wiring diagram).

Attach 100 mm of wire to the terminals of the LED and mount this in the front panel. It is advisable to insulate the terminals of the LED from each other with heatshrink tubing to prevent accidental shorts.

The mains switch should have 200 mm of heavy duty hookup wire attached to its terminals and be mounted on the front panel. Once again, heatshrink tubing should be used to cover the exposed parts of the terminals. Remember that mains voltages are lethal and any mains wiring should be double checked and any exposed terminals should be insulated with heatshrink tubing to prevent anyone (especially you — we'd like you to remain a reader) from accidentally touching a live terminal.

The front panel should now be complete. The back panel component can be mounted next. Start with the transformer. This should be securely mounted to the back panel with mounting bolts. The fuse holder and input jack can be mounted next. As with the front panel jacks the rear panel jack should have 50 mm lengths of hookup wire attached to its terminals before mounting.

The next step is to mount the mains terminal block on the floor of the box. Once this is done the power cord can be inserted and attached to the terminal block. The earth wire should be soldered to a lug and securely bolted to the floor of the box. Make sure that the position and length of the earth wire is such that it will be the last of the three wires to break if the mains cord is accidentally pulled out of the case. The mains grommet is now inserted to clamp the cord in place. The rest of the mains wiring should be completed as per the wiring diagram.



The remaining task is to mount the pc boards and wire them up. Board 2 must be mounted first. Long bolts are used so that the two boards can mount one above the other.

Once Board 2 is in position, the wires can be attached. This should be done carefully and systematically to avoid mistakes. Start with the input and output jacks and then the pots. Finally, attach 100 mm of hookup wire to the +ve rail, −ve rail and earth pegs. These will attach to the identical pegs on Board 1.

Once Board 2 has been wired, Board 1

should be mounted on top using 12 mm spacers as shown in the drawing here. Wiring up Board 1 is the same as for Board 2 except that the LED and transformer are connected on this board. Note that the two outside terminals of the secondary of the transformer are connected to the diode bridge and the two middle terminals are connected together and then to the earth peg.

This completes the construction and all that's left to do is push on the knobs, install a 1A fuse, plug it in, power it up and check that all's well. A simple voltage check with a multimeter will quickly show if you're ready to roll or not.

Using it

The first thing to do is to plug the unit into the headphone outlet of your cassette deck or amplifier. For this you will need a stereo cord with a 6.5 mm stereo plug on each end. If you can't buy one from your local stereo shop then you can easily make one. Get a suitable length of balanced microphone cable (which contains two cores plus an earth wire) and solder a 6.5 mm stereo plug on each end. This cord will plug from the headphone outlet on the cassette or amp to the input jack on the back of the Headphone Driver.

All you need to do now is plug your headphones into one of the outputs and turn the volume up to the desired level. The master gain control should initially be set to about half way and then adjusted to give a good overall maximum volume.

OK buddies — rock on (or waltz, if you prefer)! ●

PARTS LIST — ETI-462

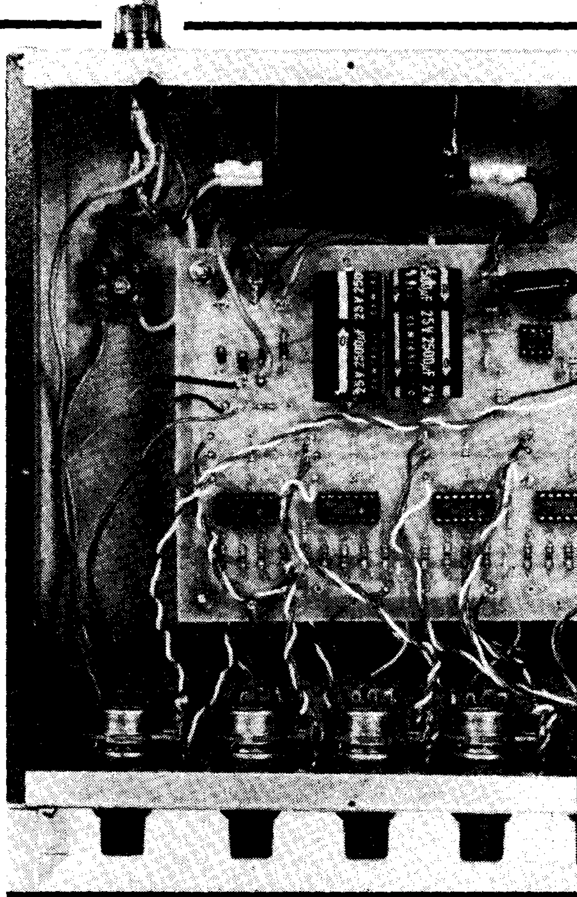
Resistors	all ¼W, 5%
R1	1k8
R2, 3, 4, 5, 6, 7, 8, 9, 10, 11	82R #
R12	15k #
R13	10k #
R14-29	15R #
RV1-RV5	100k/C dual-gang pots
Capacitors	
C1, C2	2500µ/25 V axial electro.
C3	1µ greencap #
C4-13	100n ceramic bypass #
Semiconductors	
D1-D4	1N4002 or similar
IC1	TL071 #
IC2, 3, 4, 5	TL074 #
LED1	TIL220R 5 mm red LED

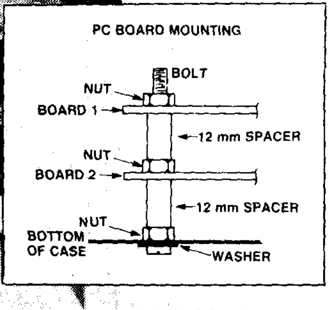
# — two of each required

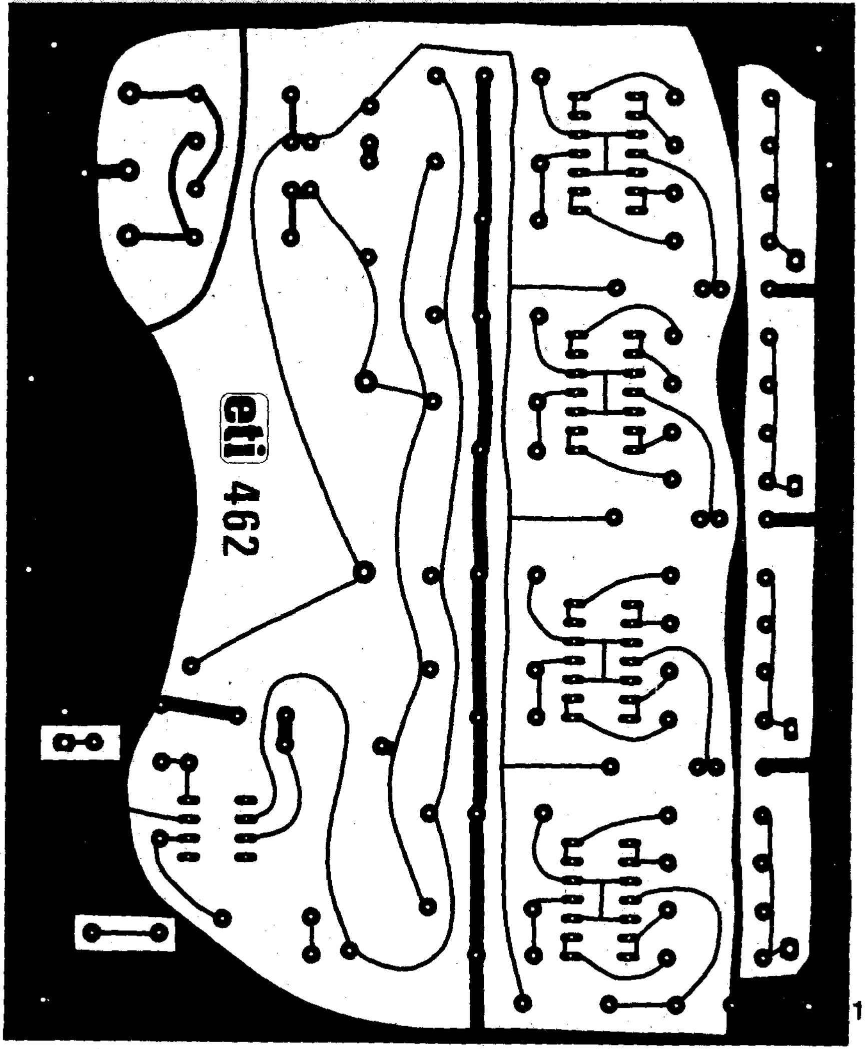
Miscellaneous	
SW1	SPDT miniature toggle switch
SK1, 2, 3, 4, 5	6.5 mm switched insulated stereo jack sockets
T1	Ferguson PL18/20 VA low profile 9-0-9 V secondary transformer.

ETI-462 pc board (two off); 5 mm LED holder; one 3AG panel mount fuse holder; 1A rated 3AG fuse; mains terminal block; 8 x 12 mm long pc board spacers; case — 203 x 76 x 228 mm — Horwood type 93/8/V or similar; Scotchal front panel label; mains cord and plug; clamp type cable grommet or grommet and cable clamp; hookup wire; nuts, bolts, etc.

Price estimate: $90-$100





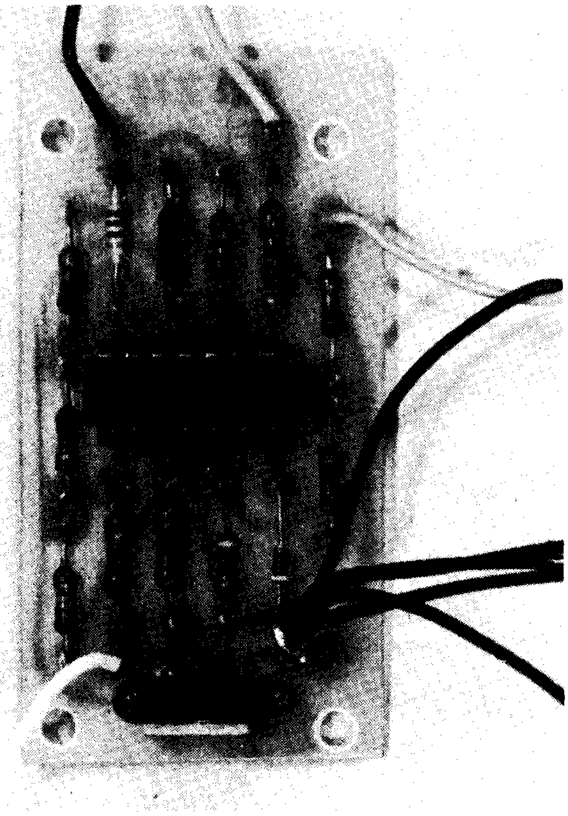


Project 272

A three-LED power level indicator for audio amps

This simple project provides indication of when your power amp output reaches three pre-determined levels. It's more useful than a simple clipping indicator (your ear is better at that!) and is cheaper and easier to install than bargraph level displays or moving coil meters.

Jonathan Scott



IT HAS BECOME the trend to include some indication of power delivered to the speakers by a power amplifier. This is a basically sensible idea. You have some idea of when you are getting near the limitation of the amplifier or the speakers, or perhaps it tells you whether the power amp is producing signal when trying to find out where the music went. It will even indicate if you are liable to be aggravating the neighbours by shaking their ceiling, assuming you are losing touch with the actual volume delivered, as one does after a long while of high level.

Many amplifiers do not have these facilities, however, my ETI Series 5000 included. (So it doesn't have much to do with actual sound quality.) Some expensive, up-market power amps come with two calibrated panel meters, which seems to be something of a waste of $40 or so, considering how often you actually need the facility. Some include only a LED 'clipping' indicator which is even less useful if it only warns of clipping, rather than getting close to it, because the ear can report this fairly reliably'.

This project was specifically designed to go in my Series 5000 power amplifier, to allow it to have some output indication while consuming only a minute amount of panel room, of which there is precious little left due to the front panel heatsink design. It sports three LEDs which turn on at power levels of one, eight and 50 watts (into 8 ohms). Should you wish to adjust the turn-on points to suit a system other than 8 ohms or power levels higher or lower than these, the equations for figuring the correct values to substitute are given in the How It Works section.

The main features of the circuit are that it does not load or interfere with the signal as the unit has a 10k input impedance, it costs very little and takes up very little room inside the case. It is also very flexibly designed, allowing the selection of any set of levels to suit different applications.

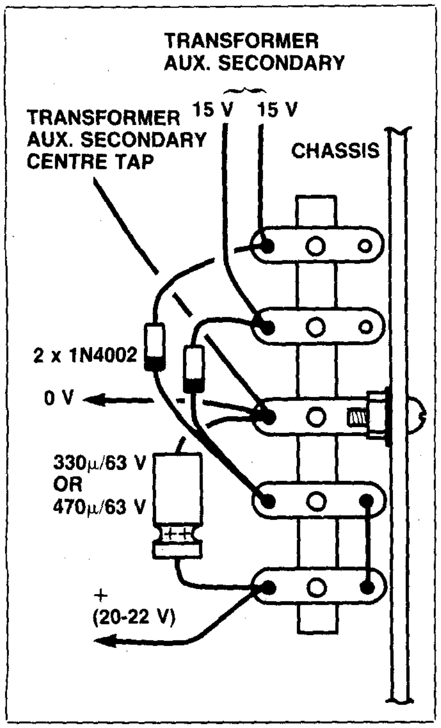
Boards can also be cascaded to give six-level readout if desired, simply by running two in parallel and selecting the appropriate resistors to get the desired levels. While I did design it as a retro-fittable addition for my 5000 amplifier, you can install it inside almost any amplifier, even a commercial one if you wish, as it has its own on-board voltage regulator and can run on any suitable filtered dc supply, and consumes little 'backroom' space and so little panel space. It could also come in useful in applications requiring a LED meter whose scale is neither linear nor logarithmic, as these are the functions often implemented in LED meter circuits.

Construction

The construction of the circuit itself is very elementary, and can be undertaken as soon as you have worked out where you are going to mount the pc board and LEDs. You should figure out where you are going to fit the board(s) and drill the appropriate holes for them and the LEDs first. You will find it convenient to use the bare board as a template for locating the mounting bolt holes.

If you are fitting a pair to a Series 5000 amplifier, you will find that they fit neatly in the space behind the power switch, bolting to the aluminium members running from the heatsink/front panel to the rear panel. It is then convenient to use the two spare windings on the adjacent power transformer to power the meters, using the circuit given here, mounting the components on a tag strip attached to one of the mounting bolts.

The six LEDs mount easily in two columns of three above the power switch. After drilling the LED mounting holes you


TRANSFORMER AUX. SECONDARY
15 V
15 V
TRANSFORMER AUX. SECONDARY CENTRE TAP
CHASSIS
2 x 1N4002
0 V
330µ/63 V OR 470µ/63 V
+ (20-22 V)

may wish to dab a little black paint on the panel to cover up the exposed metal.

The LEDs are quite good looking and unobtrusive if no mounting circlip is used at all, but rather the bare component inserted in a correct-sized hole painted black. They can be kept in place with a dab of glue on the rear of the LED body.

The pc board can be completed once the drilling is over. Simply insert and solder the components in place as per the overlay diagram. Be sure to get the diode, IC and tantalum capacitor in the right way around. You may delete the regulator from the second board and run the ground and +15 volt connections across from the first board directly.

Mount the boards in the chassis, leaving lengths of hookup wire free to be run to the appropriate places. Connect the LEDs and the power supply lines. Be sure to get these the right way around, or you will almost certainly destroy all the polarised components.

HOW IT WORKS — ETI-272

The circuit consists of a power supply regulator, which acts as the voltage reference as well, an input buffer/full-wave rectifier, and three identical comparator stages each of which drives an LED.

The circuit is designed to run on a single +15 volt supply line, which is generated by an on-board three terminal regulator. It should be noted that the supply regulator may be deleted from subsequent boards if the 15 volts line from the first board is used to directly power others. One 7815 will power four boards easily, though it might need heatsinking if handling more than two. It can also be deleted if a 15 volt supply is available already from the amplifier in which it is mounted.

IC2a and surrounding components form the full-wave rectification (or 'absolute value') circuit. It has an overall gain of 0.27, allowing input peaks of +/−50 volts comfortably. This corresponds to an RMS power level of over 150 watts into 8 Ohms, or double that into 4 Ohms. When the level on the input side of R1 is negative, IC2a drives its output positive in order to maintain the inverting input at zero volts; this arrangement produces a gain of −R2/R1, or −0.27. When the input goes positive, D1 prevents the output of the op-amp from having any effect as the diode is reverse biased. The gain input-to-output of the stage is then R3/(R2+R1), or 0.27 again. Thus, full-wave rectification takes place.

Each of the remaining three op-amps is in an identical configuration. The rectified signal is fed to the non-inverting input of each. The LED connected to the output is driven 'on' when the voltage on the non-inverting input exceeds the voltage on the inverting input. The inverting input is fed with a constant level derived from the supply rail of 15 volts by a resistive divider. Selecting the resistors and hence the division *ratio fixes* the level at which the LED turns on. The equations for selecting these resistors are given later.

Whenever the instantaneous excursion of the input signal exceeds the appropriately set level the associated LED illuminates. Thus, when the input just peaks above the set level for one LED it just illuminates for a small fraction of the cycle, giving a dim glow. When the signal comfortably exceeds the set level the LED remains on for a large fraction, giving a bright glow. The effect on the set of LEDs gives an impression of more than three discrete levels due to the analogue action appearance of the LED response. Because of this, three LEDs at carefully selected levels gives a very informative readout of amplifier activity.

In order to select the resistors associated with each comparator use the following formulae, as in the example below:

$$V_{on} = 15(R5/[R4+R5])/0.27$$

where V_{on} is the voltage at the input required to turn on LED 1.

Similar formulae are applicable for LEDs 2 and 3.

Because Power = V^2/R, (V in Volts RMS) the peak voltage associated with an RMS power level in the loudspeaker of R ohms nominal is given by:

$$V_{peak} = \sqrt{(2PR)}$$

Thus, the values of 1k2 and 15k for R5 and R4 give $V_{on} = 4.12$ and this is within 3% of the value of V_{peak} for 1 watt into 8 Ohms.

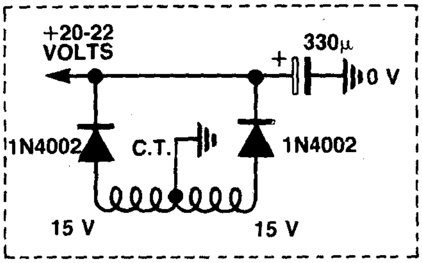
To select resistors to give a reading of ½ watt into 4 Ohms

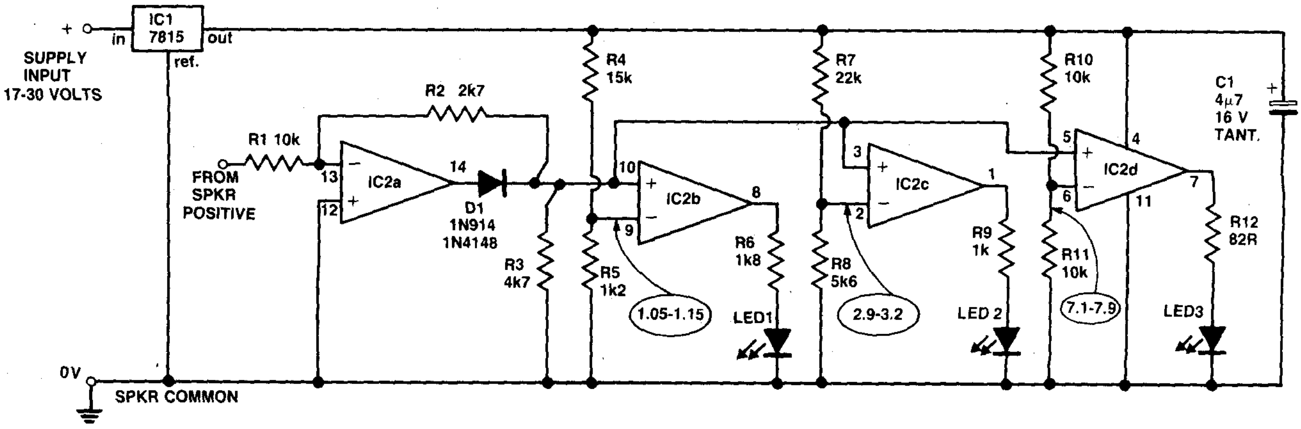
$$V_{peak} = \sqrt{2 \times ½ \times 4} = 2$$

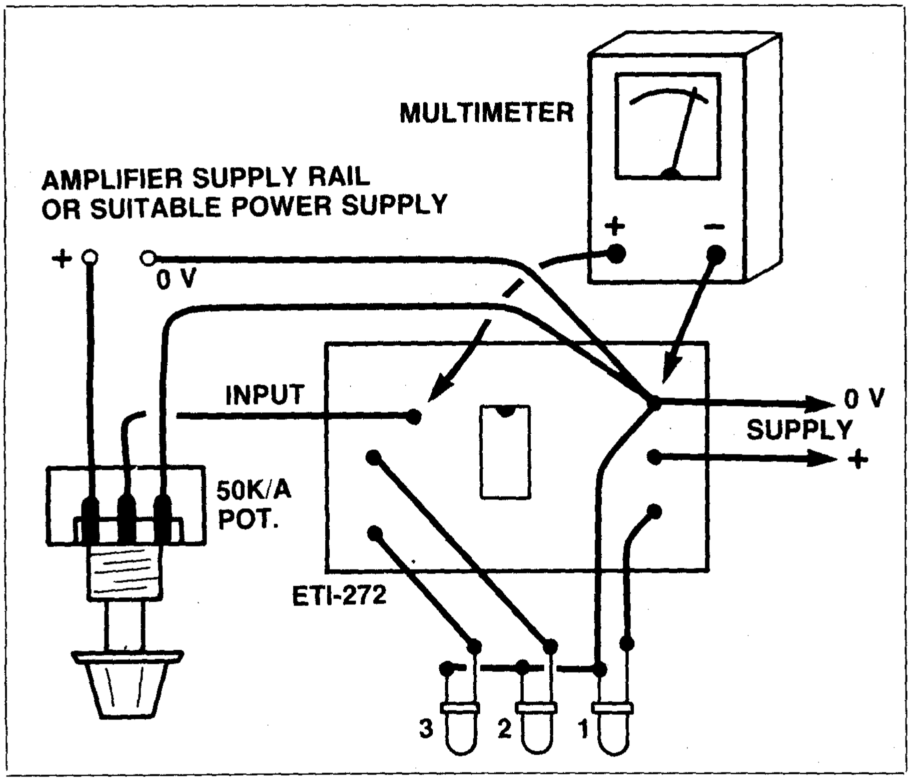
then choosing 10k for R4 we get that R5 should be about 375 Ohms; 390 is the closest, being about 4% off.

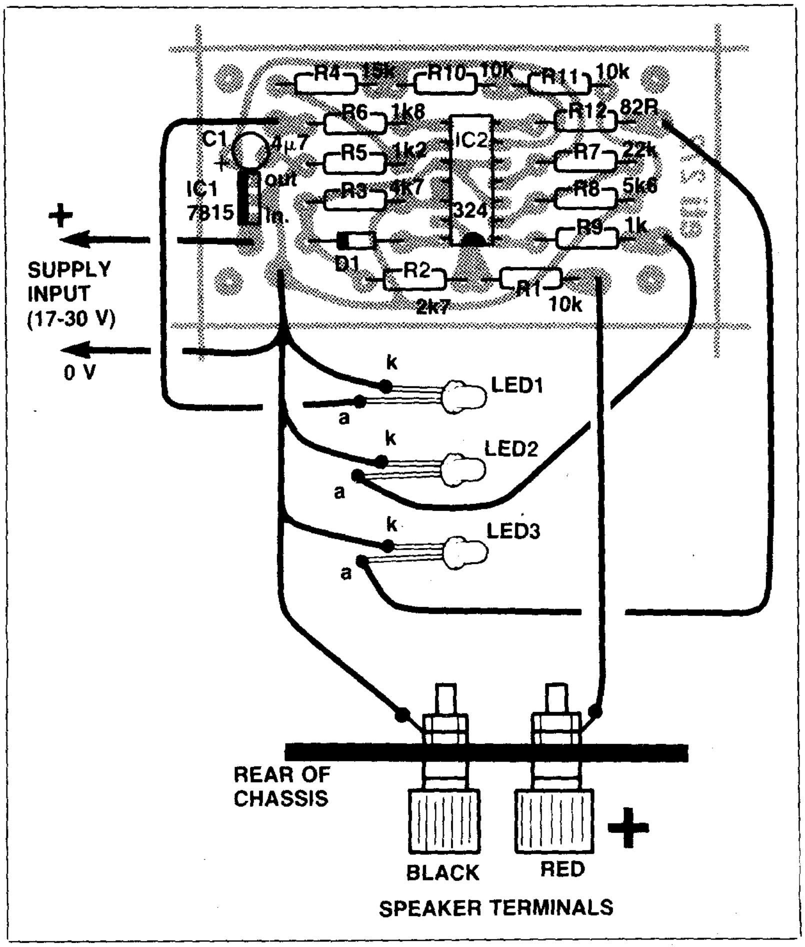
Those values could be used as R7/R8 or R10/R11 equally well.

Finally, the current limiting resistors in series with the LEDs chosen are not equal. This is in order to give rather more maximum possible brilliance to the LEDs corresponding to higher power levels. Any resistor less than a few hundred ohms will not have an effect because the current limiting effect of the op-amp output stages will dominate. A value of 82 ohms is the minimum recommended value; 1k gives slightly less brilliance, and 1k8 gives about half brightness. It is possible to have all the resistors the same, in which case any resistors of 82-220 Ohms may be used, and the op-amps will define the intensity possible.









Power up

There is no calibration required, but you may wish to test the circuit to convince yourself that it is telling the truth. Simply take the input wire for each board and, before connecting it to the speaker terminal, connect it to a variable power supply or a pot of about 50k whose end connections are at ground and amplifier rail, such that a crude source of voltage in the appropriate range is obtained, as shown in Figure 1. Connect a voltmeter to the same connection, and observe what the meter reads at each point where a LED comes on. These points will be about 4, 11 and 28 volts respectively if you are using the resistor values, given or the calculated Vpeaks if you have your own values substituted. ●

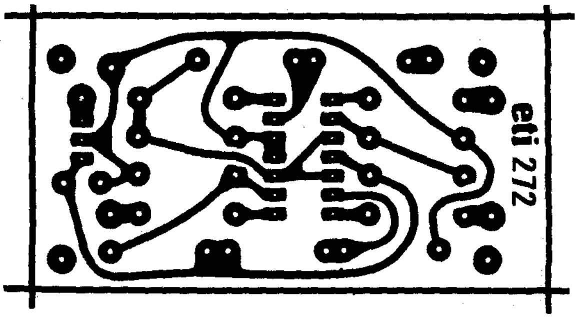
PARTS LIST — ETI 272

Resistors	all ½W, 5%
R1, 10, 11	10k
R2	2k7
R3	4k7
R4	15k
R5	1k2
R6	1k8
R7	22k
R8	5k6
R9	1k
R12	82R
Capacitor	
C1	4μ7/16 V tant.
Semiconductors	
D1	1N914, 1N4148
IC1	7815
IC2	μA324, LM324
LED1, 2, 3	TIL220 5 mm LEDs
Miscellaneous	
EIT-272 pc board; hookup wire; nuts, bolts, etc.	

Estimated price: $7-$9

Table 1. Alternate resistor values for LEDs 1, 2 and 3 to light at different power levels.

	LED1		LED2		LED3	
Power level	**R4**	**R5**	**R7**	**R8**	**R10**	**R11**
¼W	15k	560R	—	—	—	—
½W	22k	1k5	—	—	—	—
2.5W	12k	1k5	12k	1k5	—	—
4W	—	—	18k	1k5	—	—
10W	—	—	27k	8k2	27k	8k2
15W	—	—	1k	3k9	10k	3k9
20W	—	—	10k	4k7	10k	4k7
75W	—	—	—	—	10k	15k
100W	—	—	—	—	12k	27k



Ta ra, ta ra . . . the ETI loudhailer!

Build this loudhailer and make yourself heard at rallies, picnics or sporting events. Using the ETI-464 General Purpose Amp. Module mounted in the back of a locally available horn speaker, it's simple to build and quite effective.

Geoff Nicholls

PROJECTING your voice outdoors is quite a difficult task without some means of 'directing' your voice and amplifying it. Generally, you'll want to address a group of people located some distance away, or a group of people spread out in front of you for some distance. If you can direct your voice over a narrow 'beam', then less of the sound you make is wasted.

The old-fashioned megaphone did that job before 'electronics' entered the picture. Outdoor public address systems came into being with the advent of valves. For many years PA systems were cumbersome, hardly portable beasts until miniaturisation came along post World War II. The first 'loudhailer' PA systems portable by one person used miniature valves, a small horn speaker and a set of cumbersome, heavy batteries that didn't last all that long.

When power transistors came along, loudhailers proliferated. They could be held in one hand, used a small number of 'torch' batteries and did the job better than before.

The horn speaker

The horn loudspeaker is by far the best type for outdoor use. Horns can be made weatherproof and have an efficiency of better than 20% compared to a few per cent for ordinary speakers. This allows an amplifier of lower power to be used, with consequent savings in power consumption, physical size and weight.

Horns are intrinsically limited in their frequency response, and their efficiency is inversely proportional to their bandwidth. PA horns are designed to operate over the voice band at maximum efficiency. The horn itself is essentially an impedance transforming device which increases the acoustic loading on the driving diaphragm to allow better 'matching' to the air. The throat area of the horn increases exponentially as you move away from the driver.

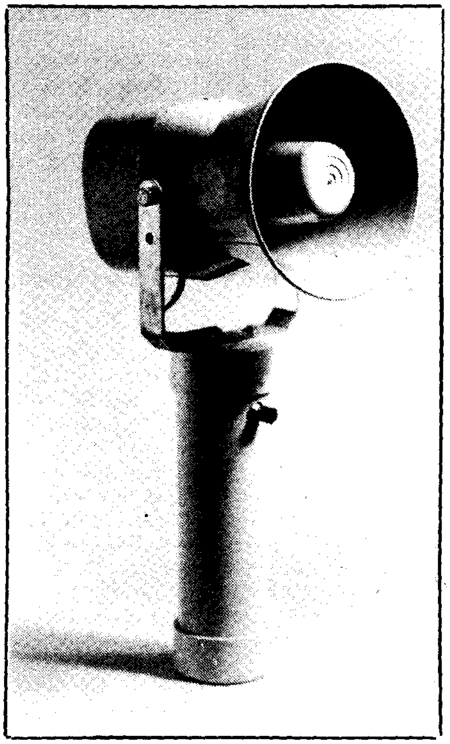
The horn may be straight, as shown in Figure 1, or folded, as shown in Figure 2. The folded horn is physically smaller and is the most common type in low cost PA systems. Folding the horn reduces the efficiency slightly but increases the coverage or dispersion, which is usually an advantage.

The straight horn has a long 'throw' and is useful for narrow sound coverage at greater distances, but is more cumbersome, especially for handheld applications!

The project

For our loudhailer, we had to search around for a suitable small folded horn. There is a variety available and prices vary widely. Probably the most common are 130 mm diameter (5") low power folded (or 'reflex') horns generally sold for boat or CB PA use. Rectangular folded horns are also available, having an opening of 200 mm wide by 120 mm or so high.

Efficiencies vary widely and are best judged by the weight! Drivers with larger, heavier magnets are more efficient than those with smaller, lighter magnets. Most have a 'dispersion angle' — the angle over which the majority of sound is dispersed from the horn — of between 60° and 90°. The narrower the dispersion angle, the greater sound level you get at a given distance from the speaker.



Your shout! Not beautiful, but effective.

The horn we chose for our prototype is imported and marketed by Benelec Pty Ltd, model no. 8-224. It is a 130 mm diameter folded horn, measuring 170 mm long overall. There is a cover on the rear of the horn with plenty of room inside to mount the power amp. module. It has a mounting

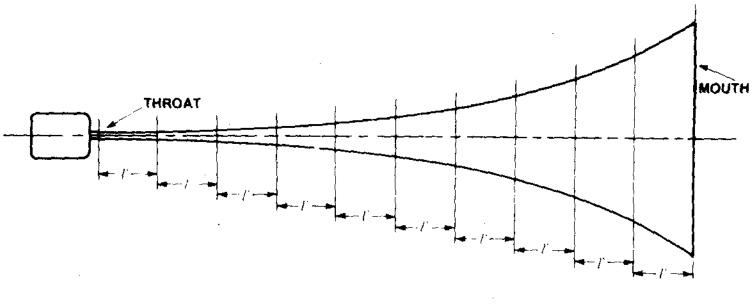


Figure 1. A straight horn has the width of the throat growing exponentially larger with increasing distance from the driver.

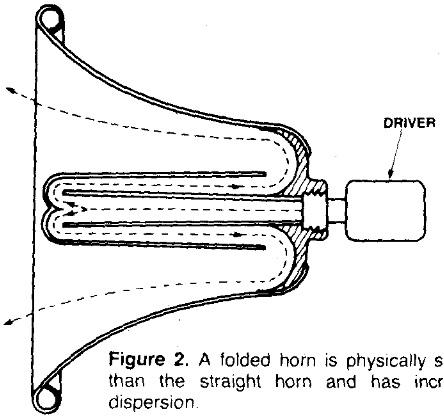
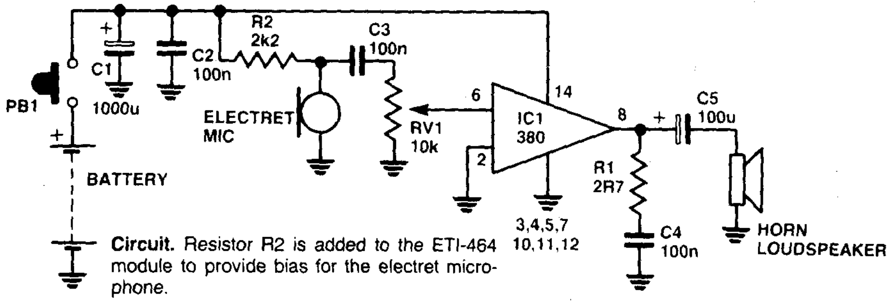
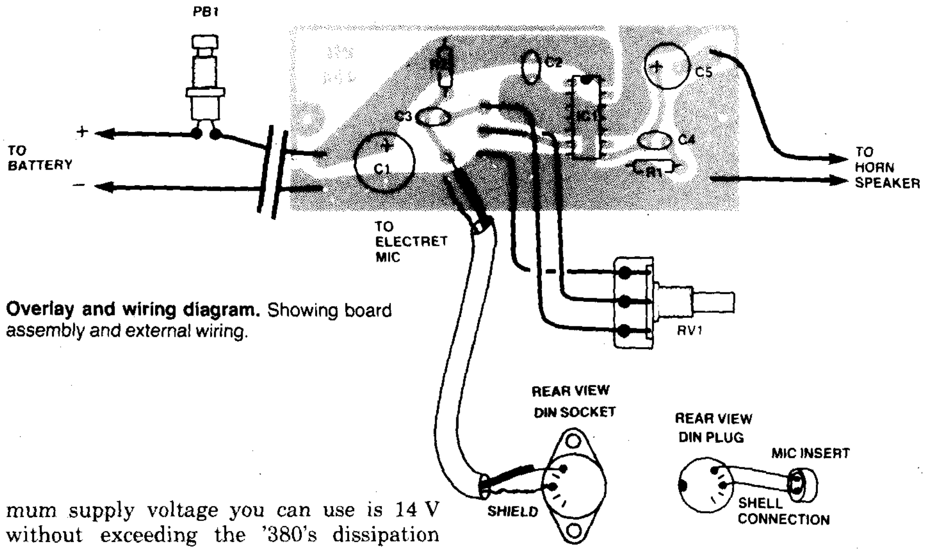


Figure 2. A folded horn is physically smaller than the straight horn and has increased dispersion.



Circuit. Resistor R2 is added to the ETI-464 module to provide bias for the electret microphone.



Overlay and wiring diagram. Showing board assembly and external wiring.

bracket that allows the horn to be swivelled over a wide range of angles. It is available with driver impedances of 4 ohms or 8 ohms, though the latter is best in this application. The dispersion angle is quoted as 60°, which we saw as desirable, and the output is quoted as being 122 dB (presumably with 1 W drive at one metre). It weighs 1.15 kg, which is not too heavy, yet ensures the sort of driver efficiency desirable for maximum effectiveness.

Using this horn, and constructing the loudhailer as described here, you can make yourself heard at 100 metres. If you don't need that much throw, then a lower cost, less efficient horn will suffice, but construction details will have to be worked out to suit yourself. See Shoparound in this issue for horn suppliers.

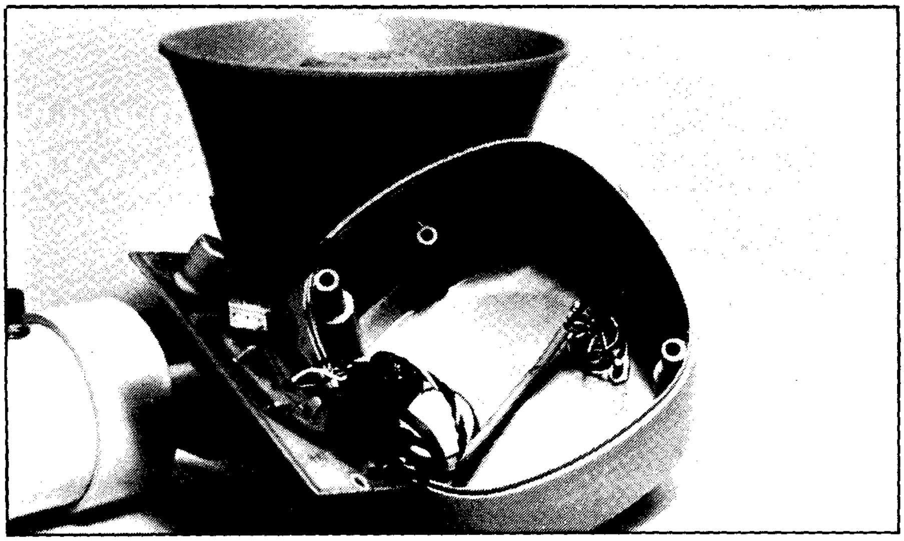
An electret microphone insert was employed to make a microphone. It proved cheap and effective. To provide a handle and battery case, a short length of 50 mm (i.d.) PVC water pipe was used, along with two end caps. This mounts, via one end cap, on the horn's mounting bracket and the batteries are slipped inside. A momentary action pushbutton switch, mounted on the 'handle', serves as an on/off switch.

Originally, I tried mounting the mic insert in the centre of the horn's rear cover, but feedback proved a problem and I couldn't utilise the full gain and output of the amplifier module. A little experimentation solved the feedback problem and improved an operator's visibility at the same time.

I mounted the mic insert in a DIN plug which plugs into a socket mounted at the top of the horn's rear cover. I also mounted a gain control pot on the cover. These measures overcame feedback problems and allowed you to see over the top of the horn.

The maximum output a '380 will deliver is five watts into an 8 ohm load using a 20 V supply. With an 18 V supply, the '380 will deliver a maximum of four watts (@ 10% distortion — which is tolerable) into an 8 ohm load. With a 4 ohm load the maximum supply voltage you can use is 14 V without exceeding the '380's dissipation rating, and you only get three watts' output. In a loudhailer, every watt counts.

Hence, I opted to use an 18 V supply. There are two ways you can arrange this with batteries. Two no. 2362 9 V batteries can be 'snapped' in series. These are 75 mm long with a male snap clip at the positive end and a female snap clip at the negative end. Alternatively, you can use 12 AA cells mounted in three four-cell battery holders. There are two advantages to the latter: the batteries last longer and the whole assembly is considerably cheaper.



Insides out. The amplifier board mounts inside the rear cover of the Benelec 8-224 horn.

PARTS LIST — ETI-465

This requires construction of the ETI-464 amp. module with the addition of the following components:

R2 .... 2k2, ¼ W/5%
RV1 .... 10k/C panel mount pot.
Electret mic. insert (e.g: D.S.E. no. C-1160); 5-pin DIN plug and socket; knob; horn loudspeaker — Benelec no. 8-224 8 ohm (see text); three 4-cell AA battery holders and clips plus 12 x AA batteries or 2 x 2362 9 V batteries and snap clips; DPDT momentary action pushbutton (e.g: D.S.E. no. C-1220); length of 50 mm PVC pipe and two end caps; wire, etc.

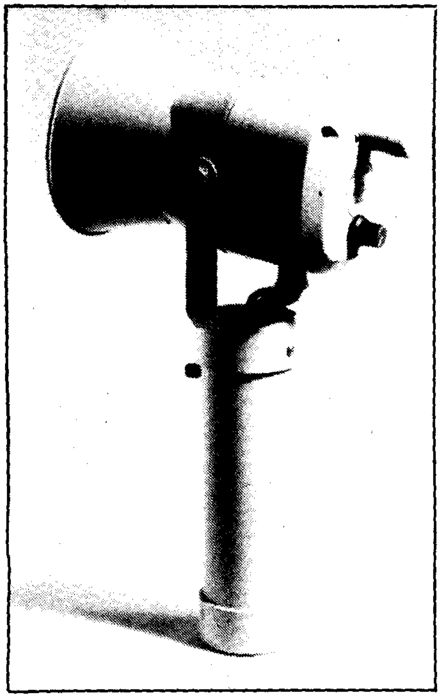
Price estimate $45-$50

Construction

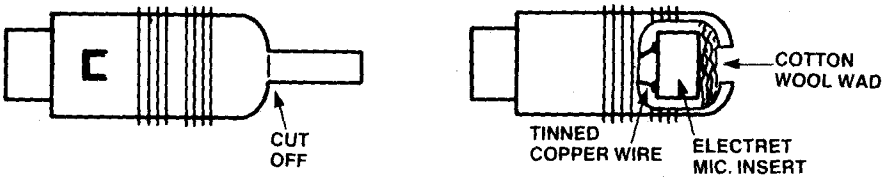
Putting the loudhailer together is quite straightforward. The ETI-464 pc board has mounting holes which match the mounting posts on the inside of the 8-224 horn speaker's rear cover. Self-tapping screws are used to mount the board and the mounting holes should be drilled to size before assembling the components to the pc board.

Assemble the power amp module according to the instructions given in the previous article on the ETI-464. Note that R2 has to be added, as shown on the overlay diagram. Don't attach any wires yet until the mechanical assembly has been completed.

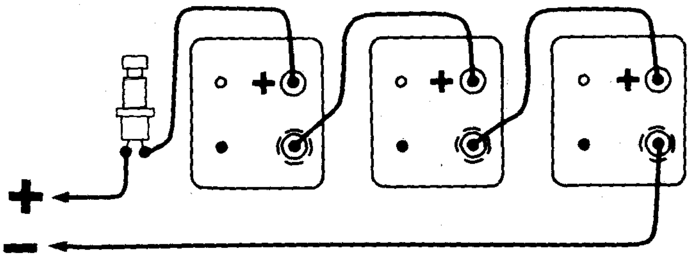
Drill the mounting holes for the volume pot and the DIN socket in the speaker's rear



Rear view. The mic plugs into the DIN socket at the top. The volume control is below it. The 'handle' houses the batteries.



Making the microphone. A DIN plug is modified as shown to house the electret mic insert.



Battery holder wiring. If you use a dozen AA cells, as I did, this is how the battery holders are wired up to provide 18 volts.

cover. The DIN socket goes at the top, the volume pot at the bottom. Also drill a hole in the bottom lip of the cover so that the leads from the battery may be passed through.

Now tackle the handle/battery compartment. Cut a 200 mm length of 50 mm i.d. PVC pipe. File the ends smooth and square and slip the end caps on. Holding them in place with masking tape, drill holes on either side, right through the cap and pipe, so that self-tapping ('PK') screws can be used to secure the end caps in place. Drill these holes to the root diameter of the PK screws.

Remove the end caps and enlarge the holes to the appropriate clearance diameter

Now take the tube and mark a hole position at the 'top' end for the on/off pushbutton switch. It should be located such that it clears the upper end cap, yet is not too far down the tube so that access to the switch connections is restricted.

Now wire up all the battery connectors, the pushbutton switch, the DIN socket, the volume pot, the speaker and the pc board. Check it all carefully when finished, then screw it all together. A little wad of sponge rubber in the upper end of the handle secures the batteries.

Now you can make the microphone. The basic assembly is shown in the accompanying diagram. We found that angling the mic insert *down* (when the unit is plugged in) helped reduce feedback problems and a tendency to 'breathiness'.

The accompanying photographs show the internal and overall assembly, when completed.

Using it

For an initial try-out, set the volume pot about halfway advanced, plug in the microphone, position your mouth about 10 mm or so from the mic, press the button and say a few words. No 'howl round' feedback or 'ringing' should be experienced, except perhaps if you're in a small room. Best try the unit outdoors.

Adjust the setting of the volume control for maximum output without feedback or ringing being evident. Always speak very close to the microphone.

If you wish, it may be convenient in some applications to have a 'remote' microphone. An electret insert can be readily installed in a CB-type handheld mic case, with the push-to-talk switch wired in parallel with the loudhailer's on/off pushbutton via the DIN plug and socket.

Happy hailing! ●

SHOPAROUND

This page is to assist readers in the continual search for components, kits, printed circuit boards and other parts for ETI projects and circuits. If you are looking for a particular item or project and it is not mentioned here, check with our advertisers.

ETI-175 handheld frequency meter

For kits of this project, try **All Electronic Components** and **Rod Irving Electronics**, both in Melbourne. The ICM7224IPL counter/display driver chip used in this project is imported and distributed by R&D Electronics. Their retail distributor in Melbourne is **All Electric Components**, and in Sydney, **Geoff Wood Electronics.**

The 4½-digit liquid crystal display is available from a number of sources. Dick Smith Electronics stock one, catalogue number Z-4175.

The case is European-made by 'Unimes' and is known as the Unimes 2. It is distributed by **Mayer Kreig** (Sydney and Adelaide) and measures 100 mm wide by 180 mm long. Depth varies from 35 to 44 mm and it has a battery compartment in the rear to take 4 x AA cells. A wire tilting bail on the rear permits standing the case up at an angle or, with the tilting bail laid flat, sitting the case flat on a benchtop.

Positive or negative film of the artwork can be obtained from the publishers for a total of $5.50, post paid. Make cheques payable to 'ETI Artwork Sales', and make sure you ask for the artwork by project number and state whether you want positive or negative film.

ETI-1502 sling psychrometer

Kits for this project should be obtained from **Rod Irving Electronics** and **All Electronic Components** in Melbourne. The low voltage metallised poly capacitors made by Wima (as specified) are distributed by **Smikron** in Sydney **(02)745-4533.** Similar types, made by Ernst Roderstein, are distributed by **Mayer Kreig** in Sydney **(02)684-1900**, and **Geoff Wood Electronics** may carry them. For the latter, values from 150n to 1μ are type MKT 1826 and values below that are type MKT 1817. Selby Scientific can supply the copper-constantin thermocouple wires (see your local 'phone book).

Positive or negative film of the pc artwork can be obtained from the publishers from $2.80 post paid. Ask for 'ETI-1502 Artwork' and make cheques payable to ETI Artwork Sales. Make sure you specify positive or negative film when ordering.

ETI-153 temp. adaptor for multimeter

Parts for this project are widely available. The AD590 temperature sensor IC is made by Analog Devices and distributed here by **Parameters Pty Ltd** who can be contacted in Sydney on (02)439-3288 or in Melbourne on (03)580-7444. The LM336 precision voltage reference made by National Semiconductor is stocked by **Geoff Wood Electronics, Jaycar** and **Radio Despatch Service** in Sydney. In Melbourne, it should be stocked by **Rod Irving Electronics, Magraths, Ellistronics** and **All Electronic Components.** Note that there are several versions and this project uses the 2.5 V type.

Kits might be obtained from **Jaycar** in Sydney, plus **All Electronic Components** and **Rod Irving Electroncis** in Melbourne.

Artwork for the pc board and front panel can be obtained for $2.00 total from the publishers, in positive or negative film transparency form. Make cheques payable to 'ETI Artwork Sales' and ensure you ask for positive or negative film, as required.

ETI-166 function/pulse generator

For a kit of this project, try **All Electronic Components** and **Rod Irving Electronics** in Melbourne. Components are widely available, so constructors should experience little difficulty in obtaining the parts. A complete set of film positive or negative artwork for all the boards and the front panel for this project can be obtained for $20.00 post paid from the publishers (includes ETI-1520 board). Make sure you ask for positive or negative film as you require; make cheques payable to 'ETI Artwork Sales'.

ETI-1520 wide band amp

Comments as per ETI-166. If you're making this project up by itself, positive or negative film artwork can be obtained for $2.80 post paid from the publishers. Make your cheque or money order out to 'ETI Artwork Sales' and make sure you specify the project number.

ETI-336 dwell meter

Two meter makes may be used for this project — the Minipa MU-65 and the University TD-86. The University meter is available at Radio Despatch Service in Sydney, while the Minipa meter is widely stocked. All other components are off-the-shelf items. Positive or negative film of the pc board and meter scale artwork can be obtained for $2.50 total from the publishers (post paid). Make sure you specify the project number and whether you want positives or negatives. Make cheques or money orders payable to 'ETI Artwork Sales'.

ETI-675 serial/parallel computer interface

The General Instruments AY-3-1015D UART used in this project is distributed by **Daneva** in Melbourne. We purchased one for the prototype from **Avtek** in Sydney. Kits can be obtained from **Altronics** in Perth, **Magraths** and **Rod Irving Electronics** in Melbourne and possibly **Avtek** in Sydney. For those making their own pc boards, film positive or negative can be obtained from the publishers for $4.00 post paid. Ask for the artwork by project number and specify whether you want positive or negative film. Make your cheque or money order out to 'ETI Artwork Sales'.

ETI-659 VIC-20 audio cassette interface

All the parts for this project are quite common and you should not have any trouble finding them. Kits will be supplied by **Altronics** in Perth, **Jaycar** in Sydney and **Rod Irving electronics** in Melbourne. **All Electronic Components** in Melbourne will also probably be stocking the kit.

Artwork for the pc board and front panel can be obtained for $5.00 total from the publishers. Ask for positive or negative film, as required, and make out your cheque or money order to 'ETI Artwork Sales'.

ETI-1522 room lights controller

A kit for this project can be obtained from **Rod Irving Electronics**, we understand. The low voltage metallised poly capacitors can be obtained from the suppliers mentioned under the ETI-1502 Sling Psychrometer project. The LM1871 and LM1872 remote controller chips can be obtained from National Semiconductor outlets. **Geoff Wood Electronics** in Sydney can supply them. The RCA triacs are distributed by **AWA Microelectronics** while the 455 kHz IF transformer set is available from **Dick Smith stores** (L-02067). The toroid specified for TR1 might be obtained through Geoff Wood Electronics or directly from Neosid in Sydney.

Film positive or negative artwork for the pc boards can be obtained from the publishers for $6.60 post paid. Ask for the artwork by project number and make cheques or money orders payable to 'ETI Artwork Sales'. Ensure you specify positivies or negatives, as required.

ETI-274 damn fast NiCad charger

Kits should be obtainable from **Rod Irving Electronics** and **All Electronic Components** in Melbourne. All the components are readily obtainable, so constructors should experience no difficulty. As usual, for those making their own boards, positive or negative film of the artwork can be obtained for just $1.00 post paid from the publishers. Make your cheque or money order payable to 'ETI Artwork Sales', and ensure you ask for positives or negatives as required. State the project number when ordering, too.

ETI-265 power down timer

Kits for this project are widely available. Try **Altronics** in **Perth, Jaycar** and **Avtek** in Sydney, **Rod Irving Electronics** and **All Electronic Components** in Melbourne.

Parts are widely obtainable. The Unibox case we used (P/N 144) is stocked by **Magraths** in Melbourne, but a wide variety of boxes would suit.

Positive or negative film transparency for the pc board can be obtained for $1.85 post paid. Ensure you specify the project number and whether you want positive or negative film. make your cheque or money order payable to 'ETI Artwork Sales'.

ETI-340 car alarm

Kits for this project are stocked by **Dick Smith Electronics, Rod Irving Electronics** and **All Electronic Components**, both from Melbourne. Components are widely available and constructors should have little difficulty obtaining their requirements.

A complete set of positive or negative film artwork can be obtained for $8.50 post paid from the publishers. Ask for the artwork by project number and specify positives or negatives as required. Make your cheque or money order payable to 'ETI Artwork Sales'.

Suitable resonance sensors are obtainable from **Technical Security Products, 102A/B May St, St Peters NSW. (02)519-6894.** Vibration microphones are obtainable from **Creative Electronics, P.O. Box 240, Matraville NSW 2036. (02)666-4000. Tandy** stores sell resonance microphones as accessories for their 49-762 alarm.

A variety of noisemakers can be obtained from **Benelec Pty Ltd, P.O. Box 21, Bondi Beach NSW 2026. (02)665-8211.**

ETI-1516 'Sure Start' ignition for model engines

Most components for this project should be readily available from almost any electronic components supplier. If you're after a kit, try **Rod Irving Electronics** and **All Electronic Components** in Melbourne.

If you're shopping around for individual components, then you'll find the FX2243 potcore is not a common item. However, you'll find **Radio Despatch Service** in Sydney plus **All Electronic Components** in Melbourne keep this component in stock. Don't forget to ask for two cup cores and a bobbin.

The potentiometers with slotted shafts were obtained from **Dick Smiths,** but you can make your own by cutting a pot shaft very short and then cutting a slit across the shaft end with the hacksaw.

You can obtain positive or negative film of the artwork to make your own boards for just $2.00 from the publishers. Specify the project number and whether you want a positive or negative when ordering. Make your cheque or money order payable to "ETI Artwork Sales".

ETI-1514 solid state switches

Kits will be available from **Rod Irving Electronics** in Melbourne, but try **Altronics** in Perth also.

If you're hunting up bits then try the following: The 4N27 is generally widely available — try **Avtek, Radio Despatch Service** and **Sheridan Electronics** in Sydney, **Billco** and **Radio Parts** in Melbourne. The higher isolation voltage 4N25 and 4N26 might be obtained from **Truscotts, Active Electronics** and **Eastern Communications**, all in Melbourne. The 4N28 is widely available, but the higher isolation types are preferred for mains applications.

The G.E. varistor, V250LA20A, shouldn't be too difficult to locate. Try **Sheridan Electronics** in Sydney and **Billco, Raycross Electronics** and **Radio Parts** in Melbourne, or Dick Smith.

The TDAJ024 zero-crossing driver might be obtained from **Jaycar, Sheridan Electronics** or **Radio Despatch Service** in Sydney, **Billco** in Melbourne. Try **Altronics** in Perth, too.

The T6000D triac isd made by RCA and distributed by AWA Microelectronics in Sydney. Try **Radio Despatch Service** and **Sheridan Electronics** in Sydney, **Billco** in Melbourne.

The MCS2400 SCR-output optocoupler is made by General Instruments (G.I.) and distributed by RIFA in Melbourne. Try Billco in Melbourne or you might politely ask **Avtek** in Sydney.

If you want to etch and drill your own pc boards, positive or negative film of the artwork can be obtained for the princely sum of $2.70. Make sure you ask for a positive or negative according to your requirements.

ETI-273 let caller

Kits for this are sold by **Dick Smith Electronics** (all over) and **Rod Irving Electronics** in Melbourne. You might also try **All Electronic Components** in Melbourne. Components are widely available. If making your own pc board and panel, film positive or negative transparencies of the artwork can be obtained from the publishers for $2.40 post paid. Ensure you ask for the artwork by project number and specify positives or negatives, as required. Make your cheque or money order out to 'ETI Artwork Sales'.

ETI-1517/1518 video amp and enhancer

The EWTI-1517 distribution amp can be used alone, but the ETI-1518 enhancer requires it along with another board.

Kits for both projects can be obtained from **Altronics** in Perth, **Avtek** in Sydney (Altronics distributor), **Rod Irving Electronics** and **All Electronic Components** in Melbourne. Components are readily obtainable.

For making your own pc boards and panel, film positive or negative transparencies of the artwork can be obtained from the publisher. The ETI-1517 board artwork costs just $1.00, while the board and panel artwork for the ETI-1518 costs $4.60 total. Ask for the artwork by project number and ensure you specify positives or negatives. Make your cheque or money order payable to 'ETI Artwork Sales'.

ETI-1521 digital exposure meter

Components for this project are generally readily available. If you can't get the BPW34 photodiode, then the BPW21 is a suitable substitute (and has a more suitable spectral response). The National 74C926 should be widely avaialble, and the 7555. The Intersil ICL7660 is obtainable through **All Electronic Components** in Melbourne and **Geoff Wood Electronics** in Sydney. You may have to hunt around for the cermet calibration pot.

Kits for this project can be obtained from **Rod Irving Electronics** and **All Electronic Components** in Melbourne.

Film transparencies of the pc board and panel artwork may be obtained for $7.00 total from the publishers. Make sure you specify the project number and whether you want positives or negatives. Make your cheque or money order out to 'ETI Artwork Sales'.

ETI-241 compact 3-way speakers

This project is stocked exclusively by **Dick Smith Electronics** and dealers, and is known as their "Series 200" speakers (cat. no. A-2370). Printed circuits (and artwork) are not sold separately. The artwork is copyright to the Dick Smith organisation.

ETI-464 general purpose amp.

All components for this project are readily available. Kits are widely stocked as well. Try **Dick Smith** stores everywhere, **Altronics** in Perth (they do it up in a nice jiffy box with a front panel), **Avtek** in Sydney (Altronics distributor), **Rod Irving Electronics** and **All Electronic Components** (you might also try **Ellistronics**) in Melbourne

ETI-412 LED audio peak programme display

The 10-LED array used in this project is imported, distributed and sold by **Altronics**, cat. no. Z-0180. Naturally, they stock the project as a kit (cat. no. K-5412). Kits might also be obtained from **Avtek** in Sydney, **Rod Irving Electronics** and **All Electronic Components** in Melbourne.

A film positive or negative transparency of the pc artwork can be obtained for $2.00 from the publishers. Specify the project number and whether you want a positive or negative. Mark your cheque or money order 'ETI Artwork Sales'.

ETI-462 headphone driver

This project uses all readily available parts, the Horwood case being widely stocked, too. **Rod Irving Electronics** and **All Electronic Components**, both in Melbourne, should be able to provide kits. Positive or negative film of the pc board and panel artwork can be obtained from the publishers for $7.60 post paid. Please specify the project number and whether you want positives or negatives, as required. Your cheque or money order should be made out to 'ETI Artwork Sales'.

ETI-272 LED audio power meter

Components for this are obtainable from virtually any electronics retail store. Kits might be purchased at **All Electronic Components** or **Rod Irving Electronics in Melbourne.** A film transparency of the artwork can be obtained from the publishers for just $1.00 post paid. Ask for it by project number and specify whether you want a positive or negative, according to requirements. Your cheque or money order should be made out to 'ETI Artwork Sales'.

ETI-465 loudhailer

This project uses the ETI-464 General Purpose Amp. project as its basis (see earlier), but **Dick Smith** stores and Rod Irving **Electronics** stock kits (albeit a little different to that described).

Printed circuit boards

Ready-made pc boards (and, often, front panels and meter scales) can be obtained through the following suppliers.

Jemal Products
P.O. Box 168
Victoria Park
WA 6100

Jaetronics
58 Appian Drive
St Albans Vic 3021

Acetronics
112 Robertson Rd
Bass Hill NSW 2197
(02)645-1241

RCS Radio
651 Forest Rd
Bexley NSW 2207

Mini Tech
P.O. Box 9194
Auckland N.Z.

All Electronic
Components
118 Lonsdale St
Melbourne Vic 3000

Rod Irving
Electronics
425 High St
Northcote Vic 3070

Billco Electronics
Shop 2, 31
Pultney St
Dandenong Vic 2175

Jaycar
117 York St
Sydney NSW 2000

Artwork sales

Orders for artwork should be sent to:

ETI Artwork Sales
ETI Magazine
P.O. Box 227
Waterloo 2017 NSW